Storm-dominated mixed siliciclastic-carbonate „Szin„ ramp (Gľac Unit of the Silicicum Superunit, Inner Western Carpathians): implication for Lower Triassic eustacy

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Abstract. The upper part of the Lower Triassic Szin Fm. in the Gľac Unit (Silicicum) comprises atypical upwards shallowing ramp-slope succession consisting of thin bedded horizontally – to wavy – laminated deposits overlain by storm-dominated, hummocky, cross stratified deposits and capped by channelised intervals of ?intratidal deposits. In the upper part of the succession, small scale compensation cycles were identified.

Bioclastic shoals growing upward in response to inherited sea-floor topography are supposed to have taken part in the carbonate factory action both by means of bioproduction and of modification of the ramp-top relief. The carbonate material was further redeposited due to wave, and especially to storm wave activity.

The overlying Szinpetri Fm. was interpreted to represent transgressive deposits at the base of a Middle Triassic carbonate sequence. Based on sequence stratigraphic analysis, the succession was correlated with the southern Silicicum and the Italian Dolomites.

Key words: ramp, tempestite, compensation cycles, sequence stratigraphy, Lower Triassic, Western Carpathians

Introduction

Origin of a ramp as a depositional environment in a passive margin setting is conditioned by a relatively low ratio of inshore to offshore production and by storm and/or wave induced offshore resedimentation (Aurel et al., 1995). Other factors, such as inherited topography of the basal surface, sediment supply, sediment type and fabric, rate and character of bioproduction, and marine circulation also affect the ramp geometry.

A prograding ramp creates a readily diagnostic facies association. The slope is that part of a ramp with the highest accumulation rate, building up a characteristic upwards shallowing sequence.

According to Burchette and Wright (1992) the „slope crest„ („ramp shoulder„, break-of-slopw, offlap- or ramp break) could correspond either to the shallowest water sediment, as in most rimmed shelves, or to the fair weather wave base transition from inner to outer shelf. The shallow flats behind the slope crest can easily be affected by storm-driven processes. Basinward streams induced by violent storm events are responsible for basinward transport in deeper neritic zone. Landward transport dominates during the vanishing stage of the storm (Rudowski, 1986, Michalík, 1997).

The resemblance to the Bouma sequence is not fortuitous in the storm induced lags, since both storm deposits and turbidites are deposited from suspension by waning currents (Nelson, 1982). While in turbulence, the transported mass behaves as a turbidity current and can create micro- and macrostructures equivalent to those of the deep-water turbidites, even in a relatively shallow water setting (Mutti & Sonnino, 1981). This suggestion remains the matter of an unjustified permanent controversy for all that. Logically, the primary sedimentary structures are responses to depositional agents rather than depositional environments, and the behaviour, not genesis, of the depositing medium is the critical aspect (Swift et l., 1987).

Compared with the ramp slope, sedimentation rates are much lower at the top flats. Generally, they can be related to the subsidence rates of the passive margin. The extremely low-angled extensive shallow flats are exposed to and might be affected by any, even small relative sea-level changes. Basin- or landward shift of facies belts would cause resedimentation by erosion or by accommodation. During periods of minor sea-level falls and lowstands, when ramps experience a loss of accommodation, sediments may be remobilized and rapid pulses of progradation and beveling of the inshore area may occur (Aurell et al., 1995). Infilling of minor highstands accommodation space is read as a parasequence of lower order in the sedimentary record.

In the case of major sea-level changes, the top ramp flats can serve as ideal basal surfaces for the development of superjacent sedimentary bodies.

General setting

The Silicicum Megaunit of the Inner Western Carpathians comprises a complex of N-NW-vergent superficial nappes. At present it is preserved in several isolated parts over an area of about 200 km by 80 km in S-SE Slovakia and NE Hungary.

Geological Survey of Slovak Republic, Dionýz Štúr Publishers, Bratislava 1999 ISSN 1335-96X

During Lower Triassic time, a large, homoclinal, low-angled to distally steepened ramp evolved on the passive margin of the Palaeo-Europian shelf (Roniewicz, 1966; Brandner, 1984; Mihalík, 1993 a, b;, Hips, 1996 a, b, 1998 a, b and references therein; Kovácz and Hips, 1998). Extensive marginal seas rimmed the Mediterranean shelf in a belt several hundred km wide. The Silicicum represents the most basinward part of this shelf domain, with a connection to the open marine environment to the south.

The lack of reef-builders in the Lower Triassic time, due to the Permian-Triassic boundary extinction event, was the crucial factor for a prolonged maintenance of ramp conditions (Hips, 1996 a, 1998 a).

Generally, the studied Lower Triassic succession has a fairly uniform lithology over the entire Silicicum. This lithology upwards changing ramp system composed of initially siliciclastic through mixed siliciclastic-carbonate an ultimalely to undiluted carbonate (marlstone) deposits served as a basement for the evolution of an extensive Middle Triassic shallow-water , carbonate, ramp association.

Lithostratigraphy

The Lower Triassic succession of the Gľac Unit in the Stratená Mts. (Inner Western Carpathians, part of the Silicicum Megaunit (Havrila, 1995), (Fig. 1) is represented by Bódvaszilas Fm. (sandy-shaley formation by Maheľ (11957), traditionally known as „Campil Beds„) (Richthoffen, 1859; Bystrický in Andrusov & Samuel, eds. 1983; Kovács et al., 1989; Hips, 1996 a, b, 1998 a, b; Mello et al., 1997). The Szinpetri Fm. comprises the uppermost part of the Lower Triassic succession. Kovács et al. (1989 cf. Hips (1996 a, 1998 a) introduced this lithostratigraphic division for the Lower Triassic sediments (overlying the Permian Perkupa Evaporite of the Silicicum in the Aggtelek – Rudabánya Mts.

Kovács et al. (1989; Hips, 1996 a, 1998 a) interpreted the Bódvaszilas Sdst. (Middle to Upper Griesbachian) as a shallow subtidal to intratidal, partly restricted, flat, coastal sediment. The Szin Marl (Nammalian – Spathian) has been interpreted as open subtidal (shallower and deeper) sediment with varying terrigenous influx.

The Lower Triassic sandy-marly sequence is overlain by Middle – Upper Triassic carbonate sequence, beginning with the Gutenstein Lmst. (Bystrický, 1982; Kovács et al., 1989). Kovács et al. (1989) divided the Szinpetri Lmst. (uppermost Spathian – lowermost Anisian) into the underlying Szin Marl and the overlying Gutenstein Lmst. They interpreted it as a subtidal – intertidal restricted lagoon facies with a decreasing terrigenous influx and with a rich benthos of low diversity, consisting only of worms. Hips (1998 a) reinterpreted the Szinpetri Lmst. in which three main facies were recognized: a storm-sheet mid-ramp facie, a dysaerobic outer ramp facies (Szinpetri Lmst.) and an anaerobic outer ramp facies (Jósvafő Mbr.).

According to Hips (1998), three succeeding depositional systems can be distinguished in the Lower Triassic succession: (1) wave- and storm-dominated siliciclastic shallow-shelf (Bódvaszilas Sdst.; (2) a mixed siliciclastic-carbonate, high energy, storm-dominated, ramp system (Szin Marl); (3) and an outer, low-energy zone of a storm-related, carbonate, ramp system (Szinpetri Lmst. ?and Gutenstein Lmst.).

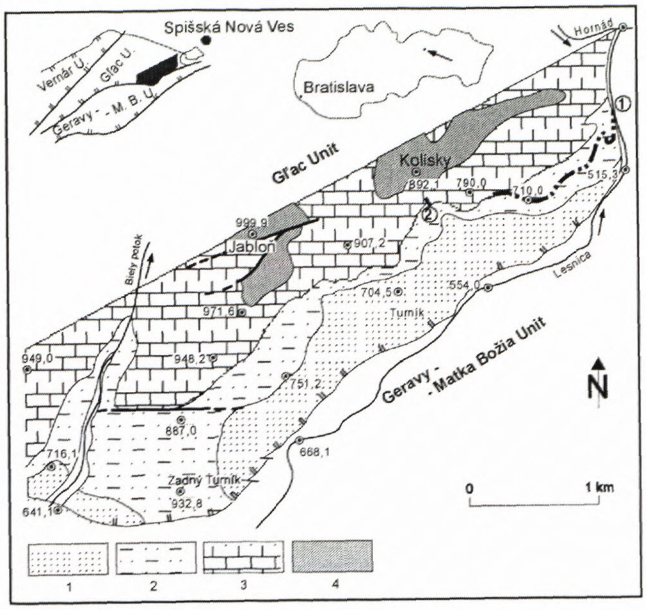

Fig. 1: Geologic map of the study area. 1. Bódvaszilas Sandstone Fm. (?U. Griesbachian-Nammalian) 2. Szin Marl Fm. (Spathian) 3. Gutenstein Fm. (L. Anisian) 4. Steinalm Limestone Fm. (U. Anisian). 1. Pf. Kolísky 1. 2. Pf. Kolísky 2. (traces with dotted line) (Because the Szinpetri Limestone Fm. is relatively thin in the study area it was mapped together with the Gutenstein Fm.).

The paleoenvironmental interpretation of the Szinpetri Lmst. will be subject to further discussion in this paper.

As seen from the regional correlation (Fig. 6), this paper deals with the upper part of the Szin Marl and the Szinpetri Lmst. to the base of the overlying Middle-Upper Triassic carbonate sequence.

In the study area (Fig. 1), several outcrops were logged in a detail. Their sedimentologic and palaeoenvironmental interpretation is the aim of the present paper. Well-documented logs and interpretations, such Maheľ & Vozár (1972), Vozárová (1977), Fejdiová & Salaj (1994) , Kovács et al. (1989), Hips (1996 a, 1998 a) from all over the Silicicum's Lower Triassic have been taken under consideration.

Lithology

This contribution explores further the interpretation of the studied succession as a low-angled southerly open ramp system. We term the Szin ramp in accordance with the name of the lithostratigraphic unit into which most of the studied succession belongs.

Because of the general paucity of fossil record, due to a slow repopulation of the shallow seas after the Late Permian world-wide extinction (Hips 1996 a, 1998 a) and thus the lack of an exact biostratigraphy, as well as the still uncertain palaeogeographic and (pre) tectonic position of individual tectonic wrecks of the Silicicum, we are not able to state the spatial relationships of the individual

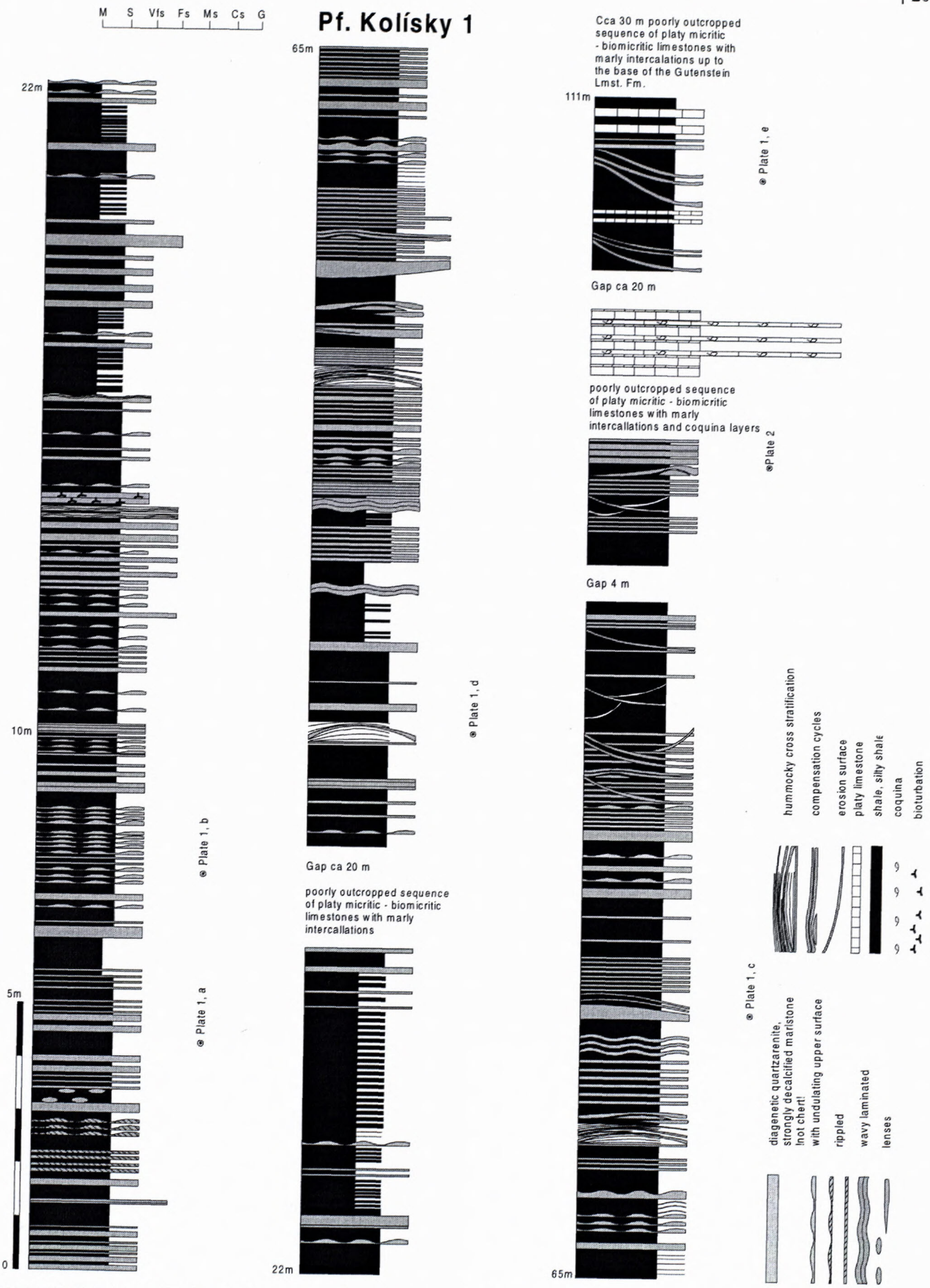

Fig. 2: Profile Kolísky 1. (At the locality, marly limestone intercalations were post-depositionally changed into diagenetic quartzarenites).

sections with certainty. The profiles at Kolísky 1, 2 (Figs. 2, 3) are shown to illustrate the general facies succession of the uppermost part of the Szin Marl and its gradual transition into the overlying Gutenstein Fm. Based on the lithologic criteria, we also infer the relationship between Szin Marl and the underlying Bódvaszilas Sdst.

The Sin Marl comprises of greenish-gray, purplish-red and dark-gray silty shale, marly shale and schistose clay-marl, which are interbedded with beige, light- to dark-brown, also pink and grey thin bedded (2-5 cm) to platy (5-10 cm) marlstone layers that have marly drapes on the bedding planes. The marly interbeds show evidence for higher energy level, including positive gradation, horizontal, flat wavy to cross ripple lamination, undulating upper surfaces and coarse bioclastic coquina lags on the bedding planes.

At a larger scale (several tens of meters), intervals of predominantly siliciclastic (shaley) deposits with ubiquitous but subordinate marly layers and of almost purely carbonate (marly) deposits occur rhythmically (Figs. 2 and 4). Coquina lags (0.5 – 2 cm) are common within the prevailingly marly intervals.

Generally, the studied succession shows clear evidence for a relative increase of energy upwards. The succession can be divided into three parts on the basis of the energy indicating sedimentary features. The marly intervals single out the parts of different energy levels.

In the lowermost part, predominantly horizontally laminated silty shales with marly intercalations are present (Plate 1, a, b). Above it, an interval of strom-dominated deposits is found (Plate 1 c, d). Farther up, the positive hummocky stratified structures are less frequent and scouring features are common. In the uppermost part of the succession there is a series of major erosion surfaces weith a mud-and-marl multiple-filled channel (3 m deep and 15 m wide) being the most prominent (Plate 1, e). The channel fill represents the topmost part of the last interval of predominantly siliciclastic deposits. It is overlain by ca 30 m complex of platy, horizontally laminated marlstone with finer drapes. Towards the top, considerably thicker (up to 20 cm) coquina intercalations occur. These possibly represent wash-over sheets derived from adjacent bioclastic shoals.

The last marlstone succesion is completely overlain by micritic - biointrapelmicritic limestone with no terrigenous influx. Vermicularly textured limestone layers are interbedded with 2-8 cm thick biointrapelmicritic redeposits and with dark-gray, thick-bedded to massive micrtites of Gutenstein facies (Bystrický, 1982; Kovács, 1989; Hips, 1996 a, 1998 a; Fig. 3).

The vermicular structure (nodular habit or burrow-mottled appearence (Hips, 1996 a 1998 a), „pseudo-nodular„ structure (Fejdiová and Salaj, 1994) may result from several genetically different processes: disturbances due to reverse density gradient (Kasinski et al., 1978), sliding (Kotanski, 1995), bioturbation or subsequent erosion (Michalík, 1997). In this case, the vermicular appearence of certain layers is obviously due to bioturbation by benthic infauna (worms) (Plate 2, b).

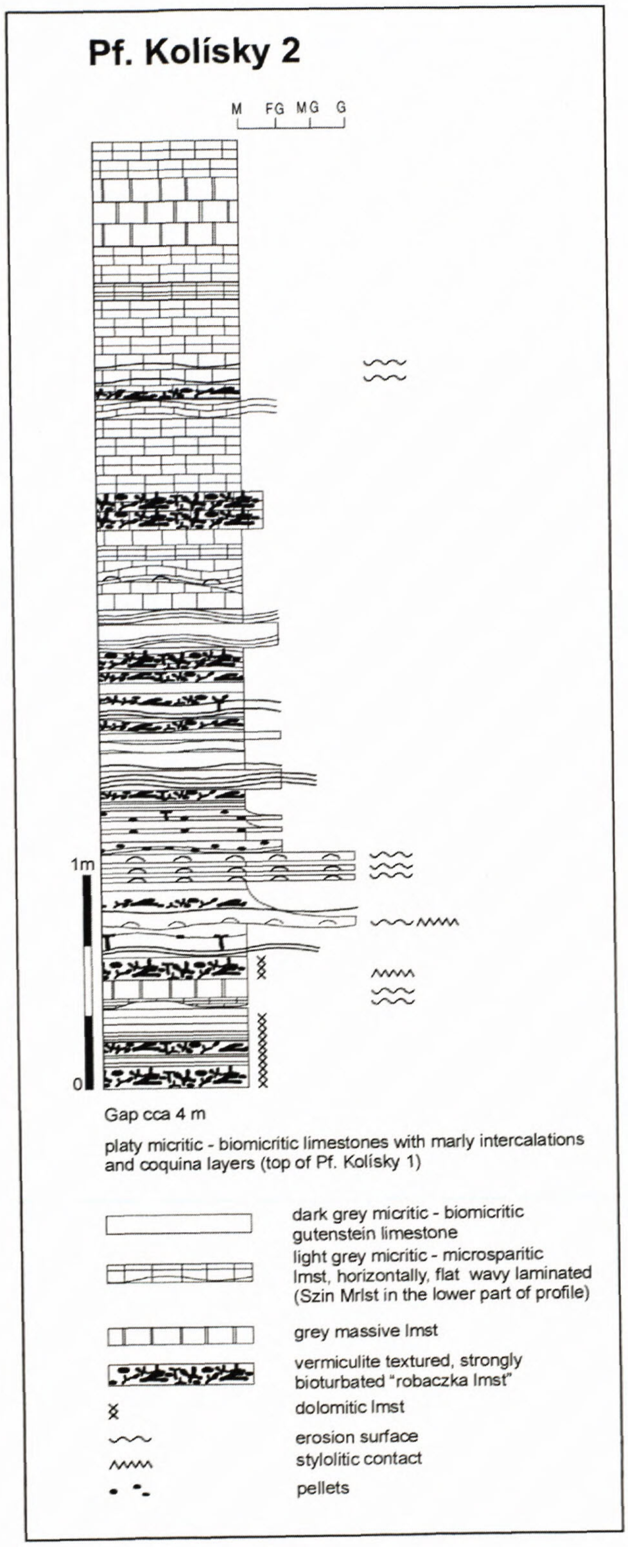

Fig. 3: Profile Kolísky 2.

The Szinpetri Limestone Fm. represents a completely different microfacies association from that of the underlying beds. It shows a close lithofacies proximity to the Gutenstein Fm. Its genetic interpretation also indicates that it is related to the overlying Gutenstein Fm. rather than to the Szin Marl Fm.

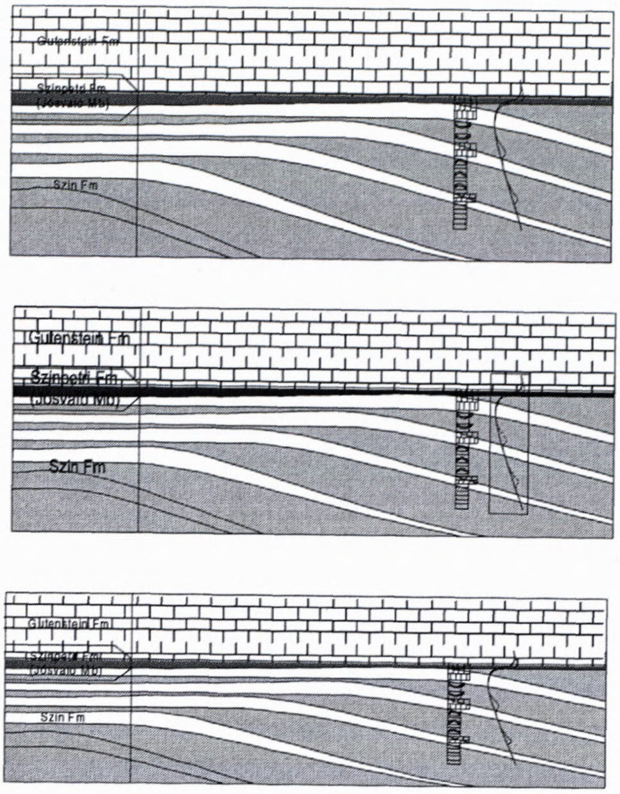

Fig. 4: Schematic cross section through the slightly inclined "Szin ramp" showing position of the profiles Kolísky 1 & 2 within its architectural framework. Marly limestone accumulations (white) are suggested to point out small-scale highstands. The Szinpetri Limestone Fm. represents main transgression.

Evidence for storm induced sedimentary processes

Remobilization of the bottom sediment and its redeposition controlled by storms is criticial in maintaining the ramp profile through time (Aurell et al., 1995; Michalík, 1992, a1997; Lavoi, 1997). Both basin- and landward sediment transport may occur during a storm event. Sea-bed topography depth, distance and sediment type and fabric control the final depositional architecture of storm deposits.

The shallow flats behind the slope crest are the place of major remobilization and erosion while slope (middle ramp) is the place of major accumulation of storm deposits. In the studied section, the marly interbeds show evidence of a rapid, single deposition. In the basal part of the succession, the abrupt change in lithology and grain size, sorting, positive gradation, horizontal, flat wavy and also cross ripple lamination are the basis for interpreting the marly interlayers as distal storm deposits.

Farther upwards, positive domical structures (hummocks) are found. These are very complex in their internal architecture and grain size (Plate 1, c, d).

Above, sedimentary structures are found whose internal architecture shows a close genetic proximity to compensation cycles, which we know from deep-water turbiditic systems (Mutti and Sonino, 1981; the pinch-and-swell structure of Swift et al., 1987).

The remobilized material is transported during storms and post-storm surges and is redeposited inshore or in a deeper region of the ramp in response to seabed topography. While reflecting the topography, the redeposited sediments build up a new small synoptic relief. Thus, an autocyclic process may develop in which each storm-induced sediment sheet is deposited in response to the previous one and predicts the depositonal architecture of the next one. This features indicate the depositon in compensation cycles as illustrated in Plate 2, a.

A sequence of sediments several meters thick that were deposited in compensation cycles is found in the upper part of the present section. Note that this horizon is situated between the hummocky-cross stratified and the scouring/redeposition dominated parts of the section. The channelized uppermost part of the succession represents the environment with the highest energy level.

Note that while the mixed but prevailingly siliciclastic deposits show obvious increases of energy level upwards, the platy marlstones remain structurally the same within the marly intervals throughout the entire succession. Although poorly outcropping in the present profile Kolísky 1, the predominantly marly intervals are well documented in many other sections. Structurally, the planar to flat wavy lamination, positive gradation, pertinent bed thickness, finer muddy marl drapes and especially the common bivalve and gastropods shells coquina lags on the tips of the beds are the evidence for which these can be precisely described as redeposits, most probably related to strom events.

It is inferred that the fine grain size of the silty shales and especially the lithological heterogeneity controlled the origin of well developed, architectonically variable storm redeposits within the prevailingly siliciclastic intervals (Plate 1). The lithologically homogenous, relatively high viscose marl did not allow such morphological variability of final accumulations and thus the well-bedded marl sheets were deposited.

Sediment source

The location of the direct sources of both siliciclastic and carbonate material is ambiguous. An extensive southerly thicking wedge of siliciclastics is thought to have rimmed the passive margin of the Palaeo-European shelf during the Upper Permian - Lower Triassic times (Roniewicz, 1966; Brandner, 1984; Michalík, 1978, 1993 a, b, 1994; Kázmer and Kovács, 1985; Hips, 1996 a, 1998 a and references therein). This idea is constrained by evidence of facies grading of fluvial and coastal to shallow and deep water open marine sediments within the Permo-Triassic successions of the superimposed nappe systems of Western Carpathians. The rapidly eroded „Vindelic Land„ is believed to have been the primary source area. (According to petrographic analysis by Vozárová (1977) and Fejdiová and Salaj (1994) the provenience falls between the recycled orogeny / magmatic fields when plotted in the triangular diagrams (c.f. Dickinson and Suczek, 1979).

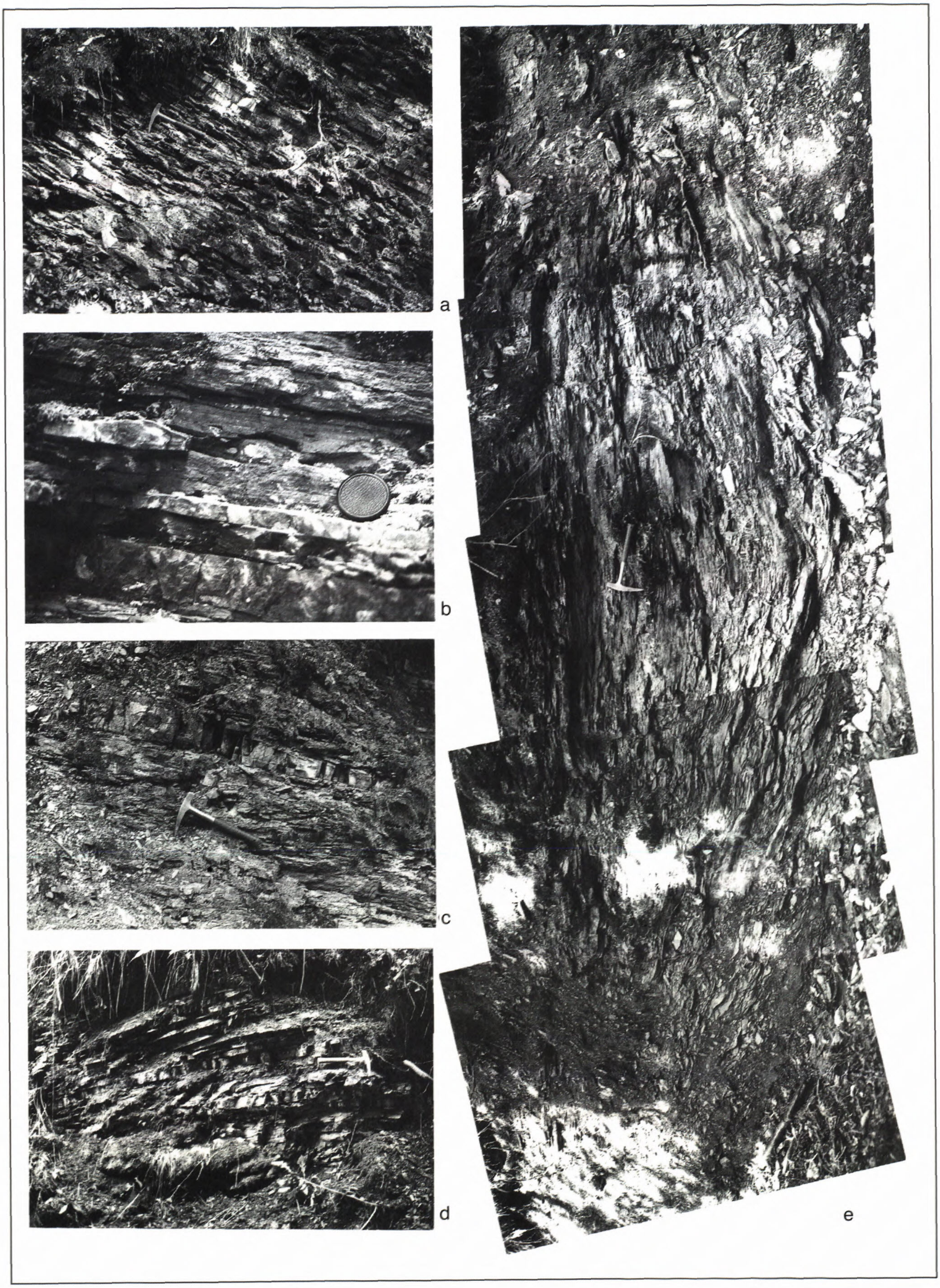

Plate I

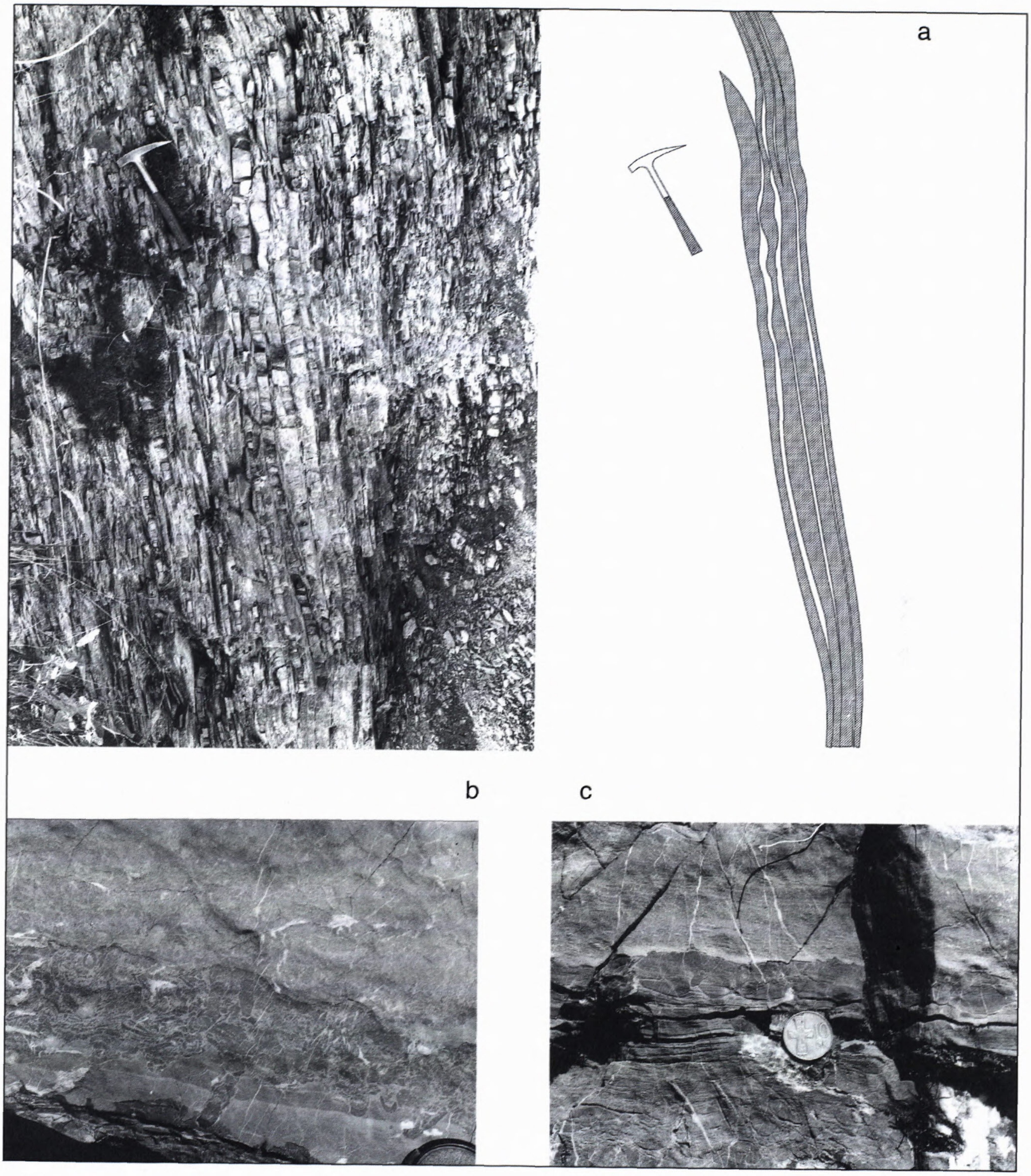

Plate II a. Detail view on a small scale compensation cycle in the upper part of profile Kolísky 1 (see Fig. 2 for exact localization). Sediments carried by marl-laden debris flows and/or turbidity currents induced by storms from adjacent lime mounds were deposited in dependence on autocyclically conditioned changes in sea bed topography. Note the lateral shift of apical, thickest parts of successive undulating layers (?turbidites). Deep scour of unknown origin on the right side of most such domatic structures is chracteristic in this part of the outcrop. **b, c:** Szinpetri Limestone Fm. (Jósvafő Limestone Mb) in the overlier of the Szin Marl Fm. **b.** Vermicular appearance is due to intense bioturbation by benthic infauna. **c.** Thoroughly bioturbated layer is scoured by biointrapelmicritic redeposite.

Plate I Sedimentary structures and depositional geometries of deposits preserved in profile Kolísky 1. See Fig. 2 for exact locallization at profile. **a**. Thin-bedded horizontally laminated shales with marly (diagenetic quartzarenite) intercalations. **b**. Marly (diagenetic quartzarenite) intercalations with undulating upper surface. **c, d**. Hummocky cross-stratified deposits in the middle part of the profile. Some hummocks are as large as 5 m wide and 1 m high (hammer for scale is 33 cm long) showing very complex internal structure. **e** About 15 m wide and 3 m deep channel in the uppermost part of the profile is filled mainly with shales, with marlstone (diagenetic quartzarenites) and biodetritic marly limestone intercallations becoming more common and thicker upwards.

In the Permian Perkupa Fm. and Lower-Triassic Bódvaszilas Sdst., which underly the studied Szin Marl, there is a clear evidence for terrestrial sedimentation. Most of the evaporitic Perkupa Fm. was deposited in a sabkha and playa type setting (Vozárová, 1979, 1996; Kovács et al., 1989; Hips, 1996 a, 1998 a). The sediments were frequently redeposited, possibly due to seasonally flooding streams. In the above, the Bódvaszilas Sdst. shows features typical for shallow subtidal to intertidal sediments. Among them, rain drops imprints on the bedding plains, dessicaton cracks, heringbone cross stratification and conglomerate-filled channels are common (Vozárová, 1997; Kovács et al., 1994; Hips, 1996 a, 1998 a).

Thus, local sources in negligibly elevated parts of the shelf domain can be taken under consideration. These local elevations could have served as additional sources of redepoisted siliciclastic material or as the places suited for later shallow-water carbonate-producing shoals evolution.

Origin of the cyclic marlstone-shale alternation

The effect of a periodic alternation of prevailingly siliciclastic (shaley) and prevailingly carbonate (marly) intervals (Fig. 2) can be linked to various controls. Progressive aridization succeeded the Lower Triassic humid event. The periodicity may thus reflect the oscillatory change of climatic conditions. The relative increase in fine-grained siliciclastic influx may have been related to brief partial shutdown of the carbonate factory during the relatively humid periods. Carbonate production may have recovered on the ramp top in response to subsequent humidity decrease.

As noted above, the shallow flat inner ramp areas are well exposed and would be affected by minor sea-level changes. Land- or basinward shift of facies belts related to erosion/accommodation effects must be considered while discussing the variable relationships among possible sediment sources, sea-level fluctuation and seabed tography. The role of relative sea-level fluctuation is constrained by two lines of evidence: a) the abrupt but long-lasting change in lithology of b) obviously redeposited sediments. The considerably different lithologies of interbedded redeposits appear to be related to the source, rather than to climatic changes at all scales on a small, as well as on a large scale. In the present section each marly interval represents a significant change in energy level. This relationship is not so obviously seen in deeper facies sections.

We do not know much about the complex geometry and the sequence-scale depositional patterns of the supposingly extremely low angled ramp system studied. This is mainly due to its considerable areal extent: the pericontinental „clastic wedge„ is estimated to have been 750 - 800 km long and 250 - 300 km wide (Michalík, 1993 a, b). The depositional area of the studied formations comprise approximately 1/3 of its extent. Significant tectonic displacements and relatively poor exposures are also problems.

Hips (1996 a, 1998 a) in her comprehensive studies of analogous formations in the Aggtelek-Rudabánya Mts. in NE Hungary suggested a complex model of the „Aggtelek„ ramp depositional system. However, the presumption that the geomorphologically determined study area would offer a complete lateral section throughout the ramp body from foreshore down to outer ramp and basin would probably be false. The vertical genetic subdivision of the Aggtelek ramp into depositional units is correlatable with relative successions from more northward (15 and 50 km) situated parts of the Silicicum megaunit (Fig. 6). Nevertheless, the position of the particular ramp (or ramps?) mentioned in the depositional system of the Lower Triassic Alpine-Carpathian shelf domain remains uncertain.

At present we do not have enough data on the ramp - slope - basin successions to be able to set up a spatial genetic subdivision of the ramp complex into depositional units. Thus, we are not even able to correlate certain sediments (shales/marls) in the studied section with specific stand of sea-level with any degree of certainty.

Two diametrically different paradigms may be chosen in order to solve this problem. In one opinion, the slope experiences a considerable increase of redeposition of eroded and remobilized inner shelf lime muds and calciclastics during the relative sea-level fall and lowstand (Hunt and Tucker, 1992, 1993; Lavoie, 1995), whereas sea transgression is the time when siliciclastic input may prevail on the drowned shelf. This concept is analogous to those used in siliciclastic systems and its application to carbonate systems may be false (Hunt and Tucker, 1992, 1993). From another point of view,Crevello and Schalger, 1980; Boardman et al., 1986; Hunt and Tucker, 1992, 1993), slope and basinal sedimentation may decrease during the lowstand inasmuch as the emerged shelf produces no or little carbonate sediment and may be affected by terrigenous siliciclastic input. Highstand is the time when the maximum growth potential of the platform (ramp) is realized and the shelf margins typically prograde basinwards (Hunt and Tucker, 1992, 1993).

As discussed later, we consider the shale/marlstone (?marlstone/shale) cycles in the lower part of the studied succession to represent parasequences (Vail et al., 1977). The problem mentioned above is where to put the parasequence boundaries.

A scheme marking the positions of the studied succession within the Szin ramp system is shown in figure 4.

Further speculation on possible sediment sources

Hips (1998 a) considered the origin of carbonate mud supplied to the ramp to remain enigmatic: it could presumably be winnowed and transported from the shallower ramp by storm-generated currents, or produced by the outer ramp (?).

Four possible relationships among contemporarily acting sources of fine siliciclastics and marls are illustrated in figure 5. The idea of carbonate-dominated shallow (e.g. warm-water, higher saline etc.) nearshore flats and shale-dominated offshore areas is hindered by about 50% of non-carbonate terrigenous shales (unmixed with the inner ramp marls) building up the ramp (a; see Fig. 2).

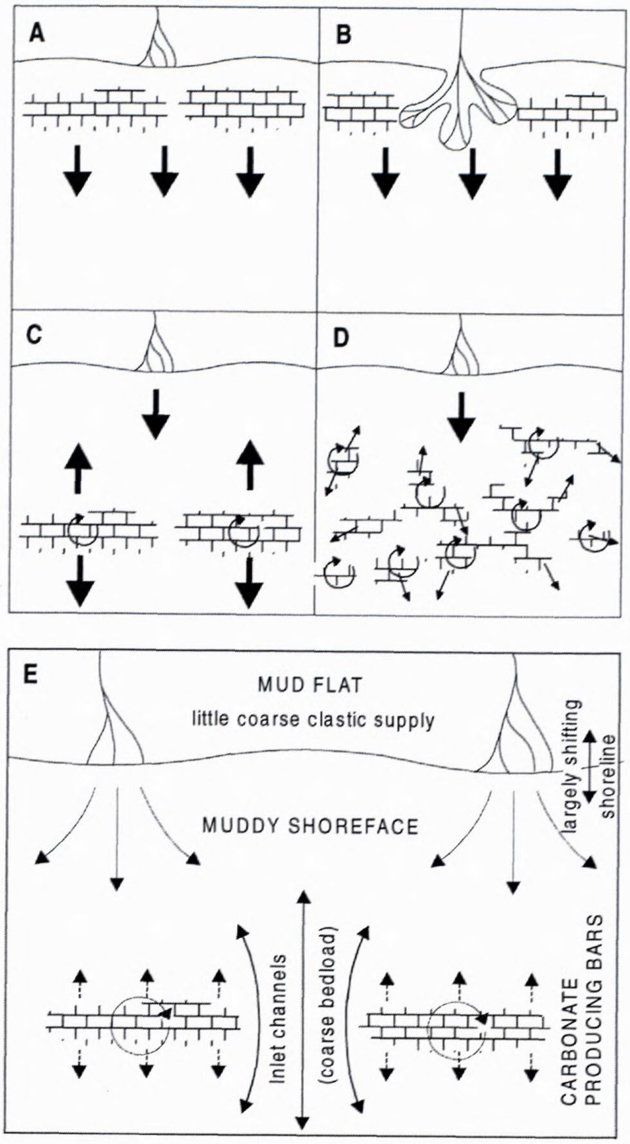

Fig. 5: Schematic view on four (A, B, C, D) possible relations between the sources of terrigenous clastics and carbonates. See E for explanation of symbols and text for discussion.

In the case (b), parallel, independent near-shore sources of both siliciclastics and carbonates, being further mixed in the more distal parts of the shelf are inferred. It would be hard to simply relate to sea-level changes the siliciclastics/carbonate ratio in a sediment supplied from such a system. Other controlling factors such as directions and rates of siliciclastic/carbonate progradation, climate, ecology, bioproduction and marine circulation should be considered to explain the described periodicity features. Aurell et al. (1995) described a similar case from the Upper Jurassic Deschambault carbonate ramp in Spain. Sand and microgravel-fed delta prograded over middle ramp but remained separate and did not induce the origin of a largely dispersed mixed carbonate-siliciclastic sequence. In figure 5 (c), the source of carbonate is located at a more distal pat of the inner ramp area.

Barrier bars may have originated in the high agitated fair weather-wave (FWW) break zone of the flat-topped ramp. The relatively high water circulation and moderated depth of the bars might have supported their subsequent colonization by carbonate-producing organisms. Thus, bioclastic shoals may have evolved in these zones. The carbonate mud and biodetritus could easily have been transported and redeposited by FWW and especially by storm weather-wave (SWW) activity, nearshore as well as in the offshore ramp areas.

An identifiable rimmed margin is lacking in the studied section and a non-rimmed ramp depositional environment is suggested (Hips, 1996 a, 1998 a). However, Fejdiová and Salaj (1994) described a thick-bedded cross laminated gastropod shells-rich oolitic grainstone accumulation („gastropodenoolite„, Mišík, 1966, 1977; Bystrický in Andrusov and Samuel et al., 1983) within an analogous section through Szin Marl Fm. to Gutenstein Fm. (Fig. 6). Accompanied hardgrounds suggest periods of arrested accumulation, probably because of an increase in water energy (Jones and Desrochers, 1992). Similar characteristics are typical of carbonate shoals accumulating above the FWWB in an agitated shallow-water setting (Wilson, 1986; Jones and Desrochers, 1992). Hips (1996 a, 1998 a) considered the ooids to have been formed in the subtidal, highly agitated surge zone on the inner ramp and piled up in fringing shoals, together with bivalve and gastropode shells. However, there were no in-situ shoals found throughout the Szin Marl Fm. The later author Hips further presumed that oolitic sand was washed out and redeposited by storms in the intershoal, shallow subtidal areas. The blanket appearence of the redeposited , amalgamated lobes of shoals reflect the rapid migration of the storm affected shoals.

An idea of independent bioclastic shoals developing in response to sea-floor topography is illustrated in figure 5 (d). Any negligible sea-floor elevation shallow enough to serve as a standing crop for carbonate producing organism could have evolved into a bioclastic shoal.

As in the case (c), breaking of FWW and thus a higher water circulation in certain zones related to sea-floor topography could have supported bioproduction on elevated domains. It also could have affected the further distribution of the produced carbonate. Naturally, storm-driven resedimentation would have played a significant role in such system.

In the „ramp-ooid-barrier complex„ facies model of Hips (1993 a, 1998 a; Read, 1985), moving ooid sand shoals were built up on the edge of the inner ramp, in the breaker-surf zone, as a result of strong, continuous wave agitation. Inner ramp and restriced lagoon were separated by shoals, from which washover fans spread out into inner ramp during major stroms. On the mid-ramp crinoidic, proximal storm sheets or hummocks bordered the outer flanks of the ooidic shoals. More distally, siliciclastic and lime sands formed flat storm sheets, with the grainsize and thickness decreasing towards the outer ramp. (The model is correlatable with the case (c) of the discussion above).

Discussion

The studied section is interpreted as an upward-shallowing succession of the uppermost part of a prograding,

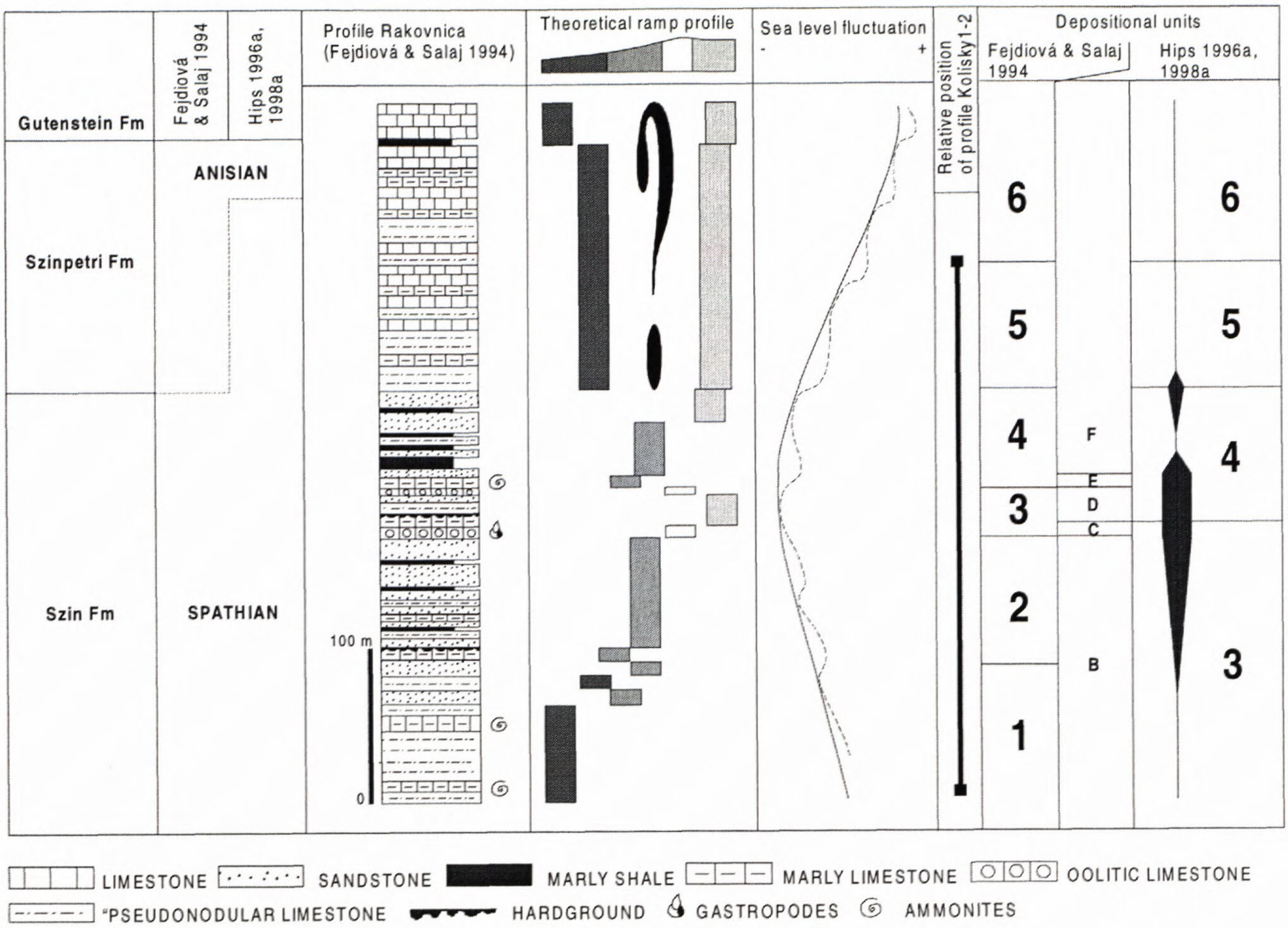

Fig. 6: Lithostratigraphic, paleoenvironmental and sequence stratigraphic interpretation of profile Rakovnica (Fejdiová & Salaj 1994) and its correlation with profiles Kolísky 1& 2 and with the synthesis on the Slicicum's Lower Triassic by Hips (1996a, b, 1998a, b). Note that the Szinpetri Limestone Fm. is much thinner (10–15 m) in the study area.

storm-dominated, gently-sloping mixed carbonate-siliciclastic ramp. The thin bedded, horizontally laminated shales/marlstones in the lower part of the present section represent a lower-middle slope facies. The storm-dominated middle part is linked to middle-upper slope facies and the scoured, erosion-resedimentation dominated, channelized, upper part of the succession is interpreted as a slope-crest-related and ramp-plain facies.

The last described part of the section is overlain by an about 30 m thick complex of well-bedded marlstone intercalated with coquina lags as much as 20 cm thick. This marlstone succession is conformably overlain by thin, well-bedded, partly bioturbated micritic limestone that is intercalated with a positively graded, horizontally laminated, biointrapelmicritic, limestone layers. These layeres commonly have often an erosive base and are clearly redeposits (Plate 2, a, b).

The well-preserved lamination and bioturbation features indicate a restricted, storm wave surges-protected, depositional environment. The redeposits represent the influence of an adjacent relatively high bioproductive area. Both the micrite and the biodetritus and other allochems have a completely different character from that of the subjacent rocks and show a close proximity to the overlying Gutenstein Fm.

The Szinpetri Limestone (Josvafő Limestone Mb.) is thus interpreted to have originated as an inner-ramp, restricted lagoon, transgressive sediment. Occurrence of foraminifera *Meandrospira deformata* (Salaj), indicates a hypersaline lagoonal environment (Salaj and Polák, 1994). Fejdiová and Salaj (1994) described a 4 m thick layer of bituminous shale in the uppermost part of the Szinpetri Limestone Fm. We interpret this as a maximum flooding surface that developed when the shelf experienced maximal drowning and the shelf lagoon became overdeepened (Hunt and Tucker, 1992, 199).

Considering the width of the Lower Triassic shelf, the biointrapelmicritic redeposits are not inferred to have been derived from either the sea- or landward shelf margin but the reverse; the existence of a local source seems probable. Topography-related bioclastic shoals are inferred ho have participated in supplying carbonate into the Szin ramp system. Locally, these could have been able to keep up with the rate of the sea-level rise and serve as a local sources from which the storm-induced redeposits were derived. Finally, these also could have served as the centers from which the superjacent Gutenstein carbonate ramp began to grow under the conditions of early highstand. The present secton Kolísky 2 may record the sedimentary fill of a locally restricted depression between the adjacent aggrading initial ramps. The inferred depression could occasionally have been influenced by storm induced sediments derived from the ramp fronts.

In contradiction to the previous interpretations of the Szinpetri Limestone as a sediment of a progressively restricted lagoon (Kovács et al., 1989; Fejdiová and Salaj, 1994; Hips, 1996 a, 1998 a), Hips (1998 a) reinterpreted it as dysaerobic to anaerobic outer ramp facies reflecting restriction due to rapid flooding of the distally steepened ramp. In this interpretation, the overying dark-grey to black, platy to massive micrites of the Anisian Gutenstein Fm. are supposed to represent the subsequent gradual filling of a restricted basin. However, the nature of the basin suggested in front of the Aggtelek ramp and the cause of its restriction remains ambiguous, due to the uncerain position of the studied ramp within the Lower Triassic Alpine-Carpathian shelf depositional system.

In the Gľac Unit the Szinpetri Limestone Fm. clearly overlies inner ramp deposits at the top of the upward shallowing ramp-slope succession. In both settings they are interpreted as transgressive deposits reflecting rapid flooding of the antecedent ramp. The overlying Gutenstein Fm. thus represents deposits of the subsequent highstand.

A turn in the ramp geometry and development of aggrading/?retrograding margin in response to the relative sea level rise was inferred in order to explain the contemporaneous restriction and limey mud production and its supply into the overdeepened lagoon. Although no such aggraded margin was found among the studied successions, it should be kept in mind that the ramp system constributed to a much more extensive shelf domain (Roniewicz, 1966; Brandner, 1984; Michalík, 1993a, b; Hips, 1996 a, b, 1998 a, b and references therein; Kovács and Hips, 1998).

Although relatively thin (10 – 15 m) and represented exclusively by the Jósvafő Limestone Fm. in the study area, the Szinpetri Limestone Fm. thickens southwards to about 100-150 m in the Slovak Karst and the Aggtelek-Rudabánya Mts. (Fejdiová and Salaj, 1994; Kovács et al., 1989; Hips, 1996 a, 1998 a). This may reflect the inner-shelf paleoposition of the Gľac Unit relative to more southward located successions, or it may support the spatial facies distribution suggested by Hips (1998 a). The latter case inferrs the deposition of dysaerobic to anaerobic Szinpetri Limestone Fm. in both drowned inner ramp lagoon and outer ramp restricted basin.

In general, we infer that relatively deeper water, upwards-shallowing Szin Marl Fm. is capped by the transgressional basal sequence of the Middle Triassic carbonate ramp complex (Szinpetri Limestone Fm. underlying the Gutenstein Fm.).

From all the evidence described we proposed a scheme of major relative sea-level movements (Fig. 6). As the Upper Permian-Lower Triassic is widely believed to have been a tectonically calm periods at the passive margin to Western Tethys, we inferr the curve to reflect eustacy to a high extent. The studied succession from the Gľac Unit is a possible analog of the units HST/3 to 6 of Hips (1996 a, 1998 a) and HST/Sc.5 to TST/An.1 of De Zanche et al. (1993) (Fig. 6).

The overall lack of fossils does not allow for exact dating either of the lithostratigraphic units of the sea-level fluctuation related events. Earlier it was accepted as a compromise that the base of the Gutenstein Fm. coincided with the Scythian/Anisian boundary. But it seems to be more realistic that the lithostratigraphic boundaries are not coeval and are generally time transgressive southwards (Bystrický 1985, Hips 1989). We involve the Hips´ (1996 a, 1998 a) litho- and biostratigraphic division of the Lower Triassic of Silicicum and use the sequence stratigraphic analysis for approximate inter-regional correlation.

Conclusions

The Lower Triassic (Spathian) Szin Marl Fm. of the Silicicum megaunit of Western Carpathians is interpreted as a low-angled, storm-dominated, mixed siliciclastic–carbonate ramp. Its upwards shallowing slope succession is subdivided on the basis of progressively increased energy of the depositional environment. The intervals of different energy levels are separated by structurally monotonous marly horizons. Several meters-thick layers were found in a certain level of the upper ramp slope succession–in between hummocky cross stratified deposits and the scouring/redeposition dominated deposits in the upper part of the present succession–in which the sediments were deposited in compensation cycles.

It is inferred that the fine grain size of the silty shales and especially the lithological heterogeneity controlled the origin of well developed, architecturally variable storm redeposits within the mixed shaley/marly intervals.

Bioclastic shoals growing up in response to an inherited sea-floor topography are believed to have taken part in the carbonate-factory action, by means of both bioproduction and modification of the ramp-top relief. The carbonate material was further redeposited due to wave and especially the storm wave activity.

From the sedimentologic and lithofacies evidence we develop a scheme of major relative sea-level movements. One major transgressive event was assumed, separating the Szin Marl Fm. from the overlying Middle Triassic carbonate complex. The Szinpetri Limestone Fm. was interpreted to represent transgressive deposits on the base of the Middle Triassic carbonate complex.

The studied succession of the Gľac Unit is possibly analogous to the units HST/3 to 6 of Hips (1996 a, 1998 a) and HST/Sc.5 to TST/An.1 of De Zanche et al. (1993).

Acknowledgements

We thank Dr. J. Mello for introduction into the field and sustainable guidance on the geology of the Silicicum. We also thank the reviewers, Drs. K. Hips and A. Vozárová, for suggestions and criticism which have improved the paper.

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