Marginal and deep-sea deposits of Central-Carpathian Paleogene Basin, Spišská Magura region, Slovakia: Implication for basin history

JURAJ JANOČKO & STANISLAV JACKO, JR.

Geological Survey of Slovak Republic, P.O. Box 13, 04 011 Košice, Slovakia

Abstract. The sedimentary fill of the Central-Carpathian Paleogene Basin (CCP Basin) in the area of the Spišská Magura region consists of Bartonian to Early Rupelian marginal and deep-water deposits. The marginal deposits are composed of breccias, conglomerates, nummulitic sandstones and limestones representing a transgressive systems tract. They are overlain by conglomerates and sandstones, shales with thick conglomerate and sandstone beds (deposits of lowstand systems tract) which, in turn, are overlain by shales containing thin sandstone and occasional conglomerate beds belonging to transgressive systems tract. The whole sedimentary succession is capped by alternating shale and sandstone beds of basin axial turbidite system deposited during lowstand of relative sea level. The main factor governing deposition in the region is tectonics, which determines the shelf width, slope gradient and sediment input.

Key words: Central-Carpathian Paleogene Basin, deep-water deposits, systems tract, sea level, tectonics

Introduction

The fill of deep-marine basins rarely consists of single type of depositional system. Controls influencing development of a deep-water system like rate, type and source of sediment supply, regional basin tectonics and sea level, usually change during a basin history. This is particularly valid for basins in an active tectonic setting where source areas, accommodation space and slope gradients may change very abruptly and thus affect type of depositional systems. The analysis of individual systems during the basin history is of main importance - it helps to understand distribution, connectivity, continuity and facies character of potential hydrocarbon reservoirs and to predict the most perspective hydrocarbon prospects.

The relatively small deformation of deposits, good outcrops and abundance of boreholes in the Central-Carpathian Paleogene Basin (CCP Basin, Fig. 1) provide an opportunity to study sediments of individual depositional systems evolving during the basin history. The thick sedimentary succession in the northern, Spišská Magura part of the CCP Basin, records deposition from initial transgression to deep-marine sedimentation. It resembles successions known from the entire northern and eastern part of the basin (Podhale, Spiš, Levoča and Šariš regions, Fig. 1), however, some sedimentary features show deposition in unique subenvironments within the basin which makes it important for understanding basin history. The main objective of the paper is to describe Paleogene deposits, their vertical and lateral facies successions (facies tracts of Mutti 1992) in the Spišská Magura part of the CCP Basin and to draw implications for the basin history based on these successions.

Geological setting

The CCP Basin lies in the northern part of the Slovakian Inner West Carpathians (Fig. 1). To the south it is bounded by the pre-Paleogene, Mesozoic and Paleozoic formations of the Inner West Carpathians. In the north it is separated from the Outer-Carpathian Flysch zone by the Pieniny Klippen Belt. The basin is developed in a forearc position on the proximal part of the accretionary wedge above the southwestward subducting oceanic slab attached to the European Platform. The kinematic history of the basin is mostly explained as a result of the escape tectonics of the North-Pannonian unit caused by the oblique subduction of the oceanic crust of the Outer Carpathian Flysch trough beneath the North-Pannonian unit (Csontos et al. 1992). However, the subduction is not proved directly, the volcanic arc is not developed and there is only minor evidence about ultrabasic rocks (Soták, Bebej & Biroň 1996) of uncertain origin (in situ? redeposited?) in the CCP Basin fill. The tectonics and sediments of the basin suggest a complex kinematic history with prevailing extensional regime and minor compression mostly occurring along the Pieniny Klippen belt. The elongated, crescent-shaped basin is about 200 km long; the maximum width is about 60 km. The northernmost part of the basin extends to the Poland where it is called the Podhale Basin (Fig. 1). The basin deposits of subaerial and marine origin with stratigraphic range Paleocene – earliest Miocene (Egerian) reach thickness around 4 000 m. The sedimentologic investigations (e.g. Marschalko 1964, 1968, 1978, 1982) resulted in a concept of prevailing deep-water deposition by turbidity flows during the basin history. Some authors divide the

Geological Survey of Slovak Republic, Dionýz Štúr Publishers, Bratislava 1998 ISSN 1335-096X

basin fill into two sedimentary cycles (e.g. Rudinec 1989). The lower cycle is represented by shallow-marine transgressive deposits and deep-water dark shales also called „subflysch deposits“ (Borové Fm. and Huty Fm. of Gross, Köhler & Samuel 1984). The upper cycle is represented by sandy turbidites (Zuberec Fm. and Biely Potok Fm. of Gross, Köhler & Samuel 1984).

The lower cycle deposits originated during initial transgression from NW and N and following abrupt deepening (collapse) of the basin causing deposition in a deep, anoxic environment (Gross et al. 1980, Baráth et al 1997, Buček et al. 1998). The pelagic deposits, condensed deposits expressed by manganese beds in the Poprad Depression, and "menilite-like" deposits have been thought

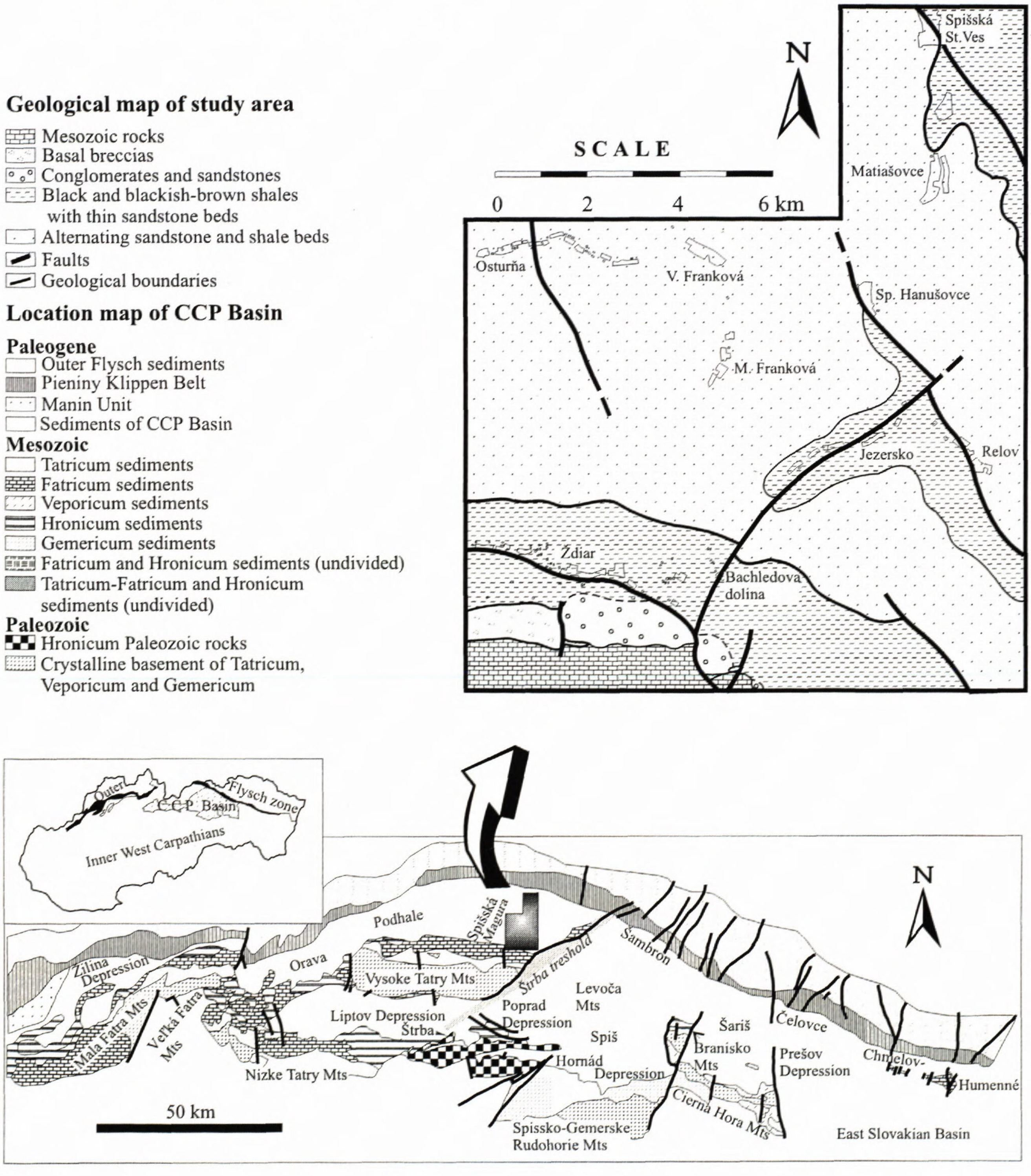

Fig 1: Location map of the study area also showing the position of the CCP Basin in the West Carpathian system and individual parts of the basin.

to record deposition during sea level rise and highstand. The collapse also caused a deposition of "muddy turbidites, flysch sediments and scarp breccias" in the Šambron Depression nearby the Pieniny Klippen Belt (Baráth et al. 1997, Fig. 1). The upper sedimentary cycle of the Central-Carpathian Paleogene Basin is supposed to be developed during the lowstand as a prograding lowstand wedge with a complex deep-sea fan zones (Baráth et al. 1997). On the basis of opposite palaoeflow directions in the deposits of the upper sedimentary cycle, two main depositional systems entering the basin from the west and south-east have been assumed. These systems should merge together in the area of Spiš and Poprad Depressions. The area was interpreted as the deepest part of the basin (Marschalko & Radomski 1960). However, our research suggests division of the basin into two basic subbasins separated by a submarine elevation trending in NE-SW direction and consisting of Štrba treshold and Ružbachy elevation (Janočko et al. 1998). Although the tectonic development of the subbasins was similar, each basin has its own depositional systems and own sedimentary history. The fans developed along the basin axis, however, the lateral sediment input into the basin was also described (e.g. Marschalko 1964, Westwalewicz-Mogilska 1986, Wieczorek 1989). In the studied area the deposits laterally entering the basin are represented by breccias, conglomerates and sandstones described as basin marginal facies (Marschalko & Radomski 1960) or Tokáreň Fan (Westwalewicz-Mogilska 1986).

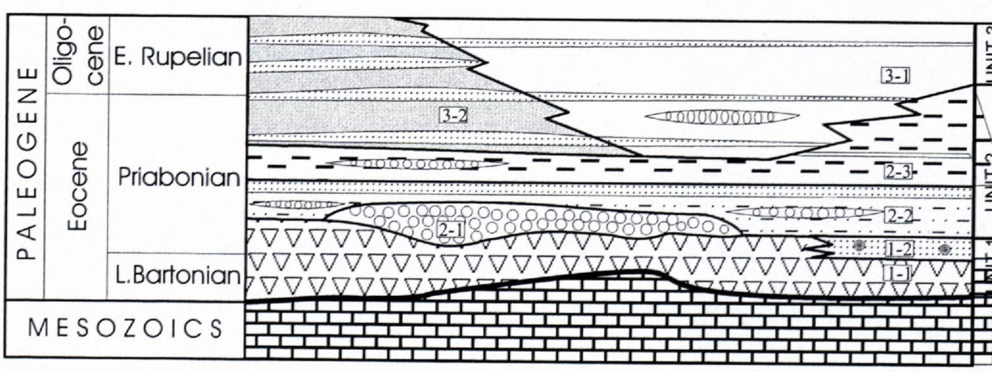

Fig. 2: Stratigraphy of the deposits in the studied area. According to Gross, Köhler & Samuel (1984) the unit 1 deposits represent Borové Fm., unit 2 deposits represent Huty Fm. and unit 3 deposits represent Zuberec Fm. The units 1 and 2 are sometimes defined as lower sedimentary cycle, the unit 3 is refferred to the upper sedimentary cycle. TST are represented by unit 1 and subunits 2-3, subunits 2-1, 2-2 and unit 3 compriese LST.

The studied area, occurring in the northern Slovak part of the CCP Basin, belongs to the Spišská Magura region (Fig. 1). The stratigraphy of this region consists of Mesozoic and Paleogene units (see Fig. 2). The pre-Paleogene units are represented by Mesozoic rocks of the Krížna nappe, cropping out in the western (Tatric) and middle (Ružbachy) parts of the region, and by the Mesozoic sequences of the Pieniny Klippen belt separating the region from the Outer Carpathian Flysch zone to the northwest. The Paleogene deposits (Fig. 2) consist of basal formation (Borové Fm. sensu Gross, Köhler & Samuel 1984) overlain by dark shales with minor sandstone and conglomerate beds (Huty Fm. of Gross, Köhler & Samuel 1984) and thick, laterally restricted body composed of poorly sorted conglomerates, mudstones and sandstones (Púcov Mb. of Gross, Köhler & Samuel 1984, Marschalko-Radomski 1960, Tokáreň Fan of Westwalewicz-Mogilska 1986). The whole Paleogene succession is capped by shales alternating with variable thick sandstones which are assumed to be a part of the basin upper sedimentary cycle by some authors (Zuberec Fm. of Gross, Köhler & Samuel 1984, Fig. 2).

Description of sedimentary successions

The post-Paleogene uplift of the Mesozoic and Paleozoic rocks of the High Tatras Mts. (ca. 15 Ma ago, Kráľ 1977, Fig. 1) also elevated the oldest, buried Paleogene deposits which now flank the slopes of the mountains. The profile from the mountains toward the deeper parts of the basin provides a complete section through the Paleogene sedimentary succession in the region. The sections obtained from outcrops were compared to archive boreholes penetrating the Paleogene succession. The thickness of the deposits in the studied area is about 1 600 m and it probably represents only a fragment of the original sedi mentary fill thickness. Based on clay mineral analysis and vitrinite reflectance data the postsedimentary uplift of at least 2 km is assumed in the area close to the Pieniny Klippen Belt in the northern part of the studied area (Milička 1998). This is supported by data from the Levoča Mts. located to the south of the studied area where a similar amount of uplift is suggested (Koturová, Biroň & Soták 1998).

The sedimentary succession was divided into three lithological units (Fig. 2).

Breccias, conglomerates, sandstones and sandy limestones comprise the base of the succession (unit 1). The age of the unit, determined by analysis of nummulite fauna, is the late Middle Eocene and Late Eocene (Late Bartonian and Priabonian, P14 – P15 zones of planktonic foraminifera, Janočko et al. 1998). The overlying deposits of unit 2 consist of three subunits: subunit 2-1 is composed of thick conglomerates filling an erosional scar cut into unit 1 and Mesozoic basement; subunit 2-2 consists of dark shales containing up to 5 m thick bodies of conglomerates and thick sandstone beds; and subunit 2-3 is composed of dark shales with minor thin sandstone and conglomerate beds. The uppermost unit 3 comprises alternating sandstones and dark shales. The analysis of nanoplankton and benthic foraminifera yielded the age ranging from the late Middle Eocene (Bartonian) to the lowermost Oligocene (Early Rupelian; NP zones 17 –21) for both units 2 and 3 (Janočko et al. 1998). Unit 2 contains redeposited large foraminifera of Early to Middle Priabonian age (P15 – P16 zones) and unit 3 contains redeposited large foraminifera of Early to Late Priabonian age (P16 – P17).

Unit 1

In the studied area unit 1 consists, from base to top, of two subunits represented by basal breccias, conglomerates and minor sandstones (subunit 1-1) and nummulitic sandstones and nummulitic sandy limestones (subunit 1-2). The maximum thickness of the unit is about 80 m but it is from a greater part reduced by erosion of the overlying subunit 2-1.

Fig. 3: Massive breccias of subunit 1-1 representing the basal Paleogene deposits in the studied region. The bar for scale is 2 m long.

The breccias of subunit 1-1 consists of angular dolomite and limestone clasts derived from the directly underlying Mesozoic basement. Massive, clast-supported structure prevails although minor layers of matrix-supported breccias also accur. The matrix is composed of poorly sorted silty sandstone occasionally containing fine pebbles. The clast size varies from a few centimeters up to 1 m. Internal organization is very poor, the clast orientation is random (Fig. 3) and it is mostly not possible to discern the individual beds. If the beds are observable, they are 1 to 2 m thick and have sharp base.

The breccias are overlain by massive, clast-supported conglomerates of subunit 1-1. The boundary between the breccias and conglomerates was not observed at any section and is not clear. The conglomerates consist of 1-15 cm angular, subangular and subrounded limestone and dolomite clasts. Locally it is possible to observe admixture of well-rounded quartz clasts having a size about 0.5 – 2 cm which comprises up to 10% of the sediment. Also redeposited tests of nummulites occur locally. The matrix consists of poorly sorted, medium- to coarse grained sandstone. The thickness of sharp and scoured based beds varies from 10 – 40 centimeters. The beds are separated by medium-grained, massive, parallel and cross-laminated sandstones comprising sharp-based beds up to 30 cm thick. The conglomerates and sandstones are often arranged into 6 – 8 m thick upward fining cycles. Amalgamation of beds can be locally observed.

Subunit 1-2 consists of sandstone, pebble sandstone and occasional sandy limestone containing nummulites. The boundary to the underlying basal breccias and conglomerates of subunit 1-1 is gradational. Sometimes the subunit directly overlies the Mesozoic limestone. The coarse-grained sandstone is massive, medium sorted and it contains nummulite tests and occasional angular and subangular pebbles of carbonates. Due to poor outcrops it is not possible to give more detailed characteristics of the subunit. The age, based on nummulite analyses (Janočko et al. 1998) varies from the Late Bartonian to the Priabonian (P 14 – P 15 zones of planktonic foraminifera).

Unit 2

Unit 2 consists of three subunits which are composed of thick conglomerate and sandstone body (subunit 2-1), dark and black shales alternating with thick conglomerate and sandstone beds (subunit 2-2) and dark and black shales with seldom thin conglomerate and sandstone beds (subunit 2-3, Fig. 2).

Subunit 2-1 consists of a thick conglomerate and sandstone body. Coarse-grained conglomerates and sandstones, reaching about 200 m thickness, overlie an erosional scar which cuts into the deposits of unit 1 or directly into the Mesozoic rocks. The vertical incision into the unit 1 is up to 60 m. The overall trend of sandstone occurrence in the subunit is increasing upward – in the lower part of the profile conglomerates prevail, in the uppermost part the conglomerates only form thin beds in sandstones (Fig. 4).

The conglomerates are mainly clast-supported and consist of angular and subangular clasts of Mesozoic carbonates (about 80%) and shales (1 – 2%), subrounded and well-rounded quartz clasts (about 10%), crystalline clasts (granitoids, melaphyres, cherts, 5%) and angular and subangular clasts of older Paleogene rocks (sandstones containing nummulites and bryozoa, conglomerates, dark shales, 3%). The sandstone and sandy limestone clasts

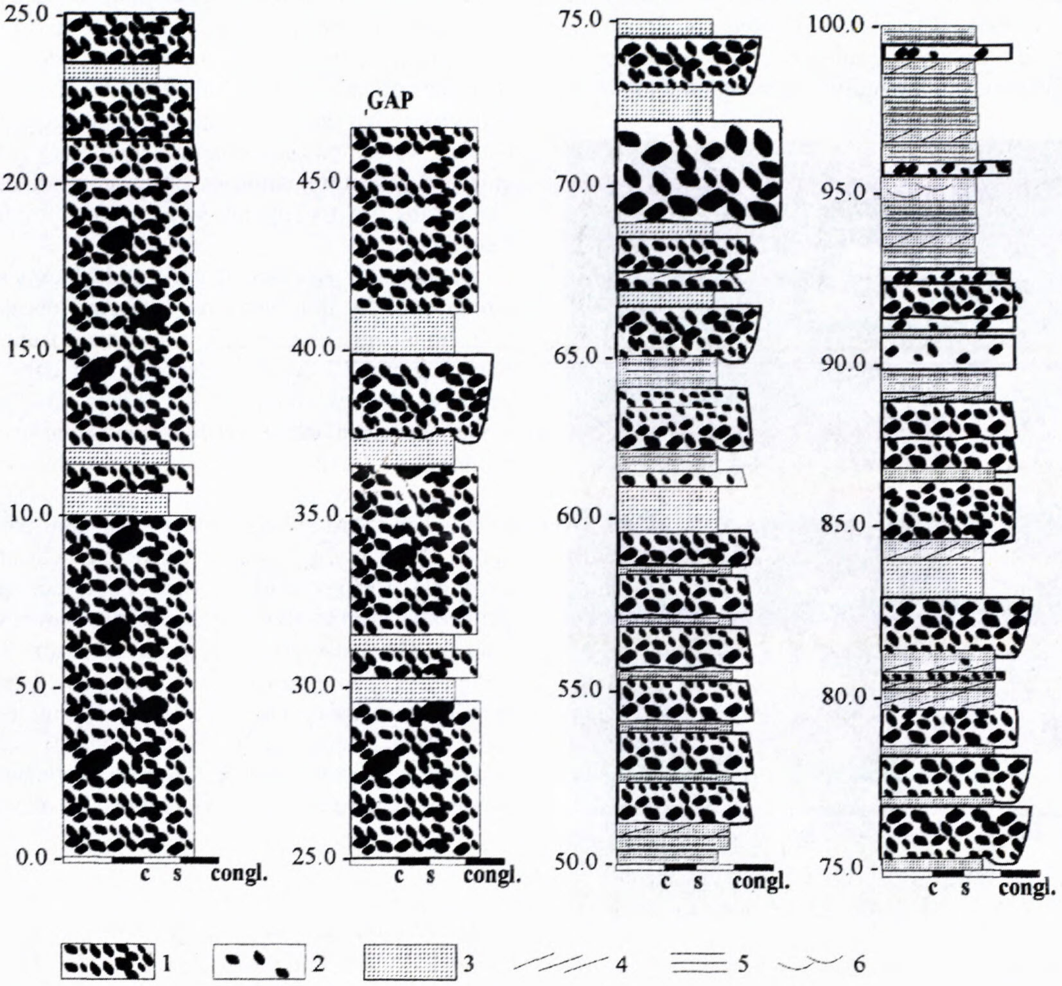

Fig. 4: Sedimentary log showing facies succession of subunit 2-1 overlying subunit 1-1. Note an increase frequency of sandstone beds on the top of the succession. 1 – clast-supported conglomerates, 2 – matrix-supported conglomerates, 3 – sandstone, 4 - cross stratification, 5 - parallel lamination, 6 – trough cross-stratification

contain *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC suggesting their Late Bartonian age (planktonic P 14 zone). The clast size of the conglomerates is variable (dolomite clasts up to 100 cm in diameter were observed) and does not show any trend along the profile. The beds are 30 cm to 2 m thick and in the lower part of the unit they are often amalgamated, forming up to 10 m thick bodies separated by thin sandstone beds (Fig. 5). The thickness and frequency of beds decreases upward (Fig. 4). The base of the beds is sharp and erosive. Flute casts developed at the base of some beds in the upper part of the unit show palaeoflow direction toward east. Maršalko & Radomski (1960) found palaeoflow indicators suggesting transport toward N in the lower part of the unit. The conglomerates are prevailingly massive in the lower part and normally and inversely graded in the upper part. The conglomerate beds are separated by pebbly sandstones and medium to coarse-grained sandstones. The sandstones are horizontally laminated and cross-stratified, occasionally normally graded (facies F 4, 5 and F6 of Mutti 1992). Water-escape structures are common (Fig. 6). The pebbles in pebbly sandstones either float in sandy matrix or they form bases of scours. The sharply-based sandstone beds are from a few centimeters to 80 centimeters thick.

Subunit 2-2 consists of black and blackish-brown shales alternating with thick conglomerate and sandstone beds. The shales have macroscopically massive appearance and in thin sections they occasionally show a faint parallel lamination. The Rtg analysis reveal quartz and sericite as main shale minerals. The carbonate content is low with mean value 7%. The mean TOC content is 0.7% (Milička 1998).

The medium-grained, lithic and compositionally immature sandstone, interbedding shales of subunit 2-2, is massive, non-graded and corresponds to F5 facies of Mutti (1992) or facies S3 of Lowe (1982). The sharply based beds are 5 to 30 cm thick. Exception is a conspicuous, 4 m thick sandstone bed set at the top of the subunit. It consists of medium grainedmassive sandstones (Mutti's F5 facies) and contains rip-up mudstone clasts in the lower part of the beds. The individual beds are 30 – 50 cm thick, amalgamated and occasionally separated by shale drapes. The base of beds is sharp and scoured.

The sharply-based conglomerate beds of subunit 2-2 are up to 5 m thick. The clast-supported conglomerates prevail, and the roundness, grain-size and composition of clasts strongly varies in the individual conglomerate beds.

Fig. 5: Alternation of conglomerates and sandstones in the upper part of the canyon fill. The size of the cliff on the photo is about 15 m

The most frequent are subangular clasts of dolomites and limestones having a size from 1 cm to 40 cm. Quartz clasts, up to 5 cm in size, are well rounded and usually represent about 5 – 10% of all clasts. Crystalline clasts and clasts derived from underlying Paleogene deposits (shales, sandstones and conglomerates) are of minor occurrence. The orientation of clasts is random. The conglomerates are mostly massive, normal grading is less frequent.

Subunit 2-3 consists of dark and black shales rarely interlayered by thin sanstone beds and occasional conglomerate beds. The subunit is separated from the underlying subunit 2-2 by a gradational boundary marking a decrease of thick conglomerate bodies. The boundary is tentatively given above the thick sandstone bed set of the subunit 2-2 (Fig. 2). The dark and black shales are similar to shales of subunit 2-2. Macroscopically they are massive and in thin sections they show a faint parallel lamination. The sharply based conglomerate beds are up to 10 cm thick. The prevailingly clast-supported, pebble conglomerates are massive and sometimes they are normally graded. The clast composition is the same like in the subunit 2-2. The sandstone beds are up to 20 cm thick and have a sharp base. They are composed of medium and fine-grained sandstone. The sandstone is massive and rarely it is parallel and ripple-cross laminated showing Bouma's T_{bcd} and T_{cd} divisions (facies F9 of Mutti 1992).

Unit 3

Unit 3 consists of alternating sandstone and shale beds and occasional thin conglomerate beds. The transition from unit 2 is gradual and marked by increasing frequency and thickness of sandstone beds. The alternating

Fig. 6: Coarse-grained, normally-graded sandstone of subunit 2-2 with water-escape structure. Note the sharp base of overlying conglomerates. The deposits are interpreted as a part of a canyon fill

sandstone and shale deposits may be divided into two subunits based on sandstone:shale ratio and sandstone bed thickness. The spatial distribution of both subunits varies both vertically and laterally.

Subunit 3-1 consists of black and dark brown massive and horizontally laminated shales, and occasional ripple-cross laminated silt streaks alternating with sandstone beds with sandstone: shale ratio from 1 : 2 to 1 : 4. The sandstone is fine and medium-grained, massive or horizontally and ripple cross-laminated (facies F5 and F9 of Mutti 1992). The thickness of beds usually does not exceed 15 cm. Laterally they pinch out very slowly, in a 2.5 km long section a 30 cm thick bed thinned to 5 cm thick bed (Fig. 7). The base of beds is sharp and scoured and frequently loaded, flute casts and groove marks indicate a palaeoflow direction toward SE and E. The conglomerate beds are sharply-based and up to 15 cm thick. The exception is a 30 m thick slump body composed of conglomerates with chaotic structure. The conglomerates consist of Mesozoic carbonates, quartz, granitoids, metamorphic rocks, Mesozoic and Paleogene sandstones and shales.

Subunit 3-2 consists of alternating sandstone and shale beds with ratio 1:1, 1:2 (Fig. 8). The shales have the same characteristics as shales in subunit 3-1, the massive and normally graded sandstones are medium to coarse-grained, faintly horizontally and ripple cross-laminated. The thickness of sandstone beds varies from 5 cm to 70 cm, sometimes they laterally pinch out. The base of beds is sharp, scoured with flute casts and groove marks suggesting palaeotransport direction toward east and southeast. Occasionally, starving ripples and synsedimentary slump folds occur (Fig. 8). In the sandstone nummulites of the Priabonian age were found.

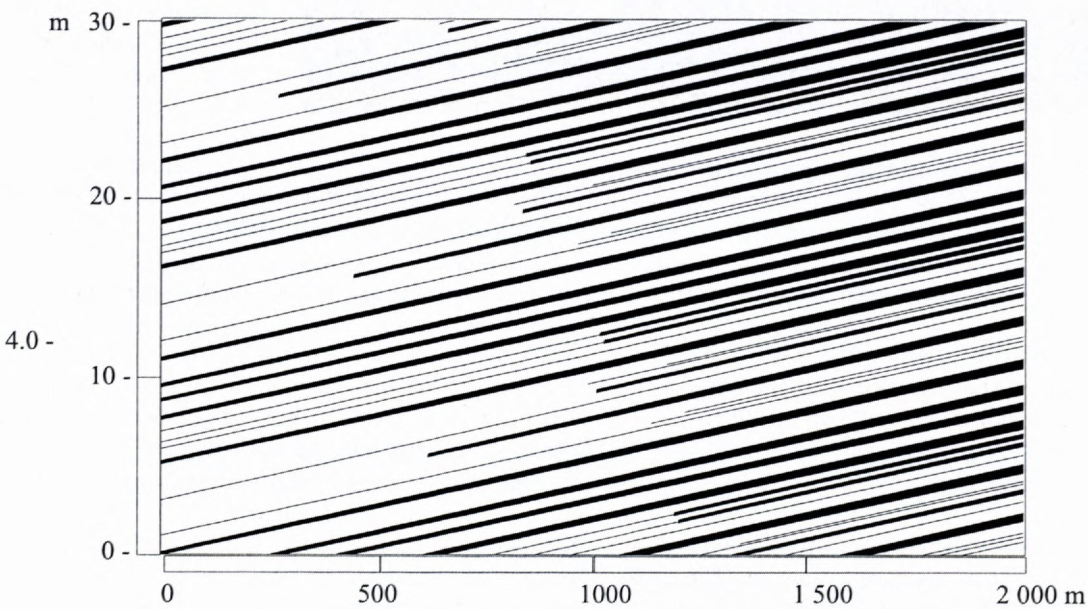

Fig. 7: Lateral pinching out of overbank deposits of unit 3. The scheme is based on the logging of a 2 km long outcrop nearby Matiašovce (for location see Fig. 1).

The massive matrix- and clast-supported conglomerates comprise sharply-based beds tens cm thick. The clasts are 1-3 cm in diameter and are composed of carbonate rocks, quartz and rarely of crystalline rocks.

Interpretation

Unit 1

The features of the breccias of subunit 1-1, sharp-edged clasts of coarse gravel to block size, poor sorting, weak internal organization as well as composition of clasts derived from the directly underlying Mesozoic basement, suggest extremely short transport during deposition. The lack of internal organization of the breccias and the occurrence of large carbonate clasts suggest prevailing rock fall depositional mechanism in front of cliffs of a high relief shore. The overlying conglomerate beds separated by sandstones are better internally organized. The scoured and sharp bases of conglomerates, their massive character, poor sorting, occurrence of separating parallel and cross-laminated sandstones and fining-upward trend in 6-8 m thick cycles hint at deposition by fluctuating traction flow. The admixture of rounded quartz clasts in the conglomerates, which do not occur in the surroundings of the studied area, suggests a distant source area. We think that these sediments were deposited on a high gradient slope in a delta fan environment by hyperpycnal flow (e.g. Bornhold & Prior 1990). The quartz clasts were transported by a fluvial system and distributed in a fan delta. The fluctuation of the flow was probably cuased by allocyclic mechanism (tectonics?, climate?).

Poor outcrops of the nummulitic sandstone and sandy limestone forming subunit 1-2 does not allow to make

Fig. 8 Levee deposits of subunit 3-2. Note a sedimentary fold in the middle of the photo.

more precise conclusions concerning depositional environment. The gradual transition from the underlying conglomerates of subunit 1-1 and the occurrence of well-preserved fragile tests of nummulites (E. Köhler, personal comm. 1999) throughout the sandstone and limestone point to their position *in situ.* The lack of any tractional structures is thought to be a result of sediment homogenization by burrowing. The presence of nummulites suggests an environment with water depth up to 100 m.

Unit 2

Conglomerate and sandstone deposits of subunit 2-1 are interpreted as a fill of submarine canyon. The estimated 60 meters of incision into underlying unit 1 suggest a striking relative sea level fall. The clast composition of conglomerates suggest several source areas. The dolomite and limestone clasts were probably derived from the local coast formed by Mesozoic rocks. The crystalline rocks did not occur in the vicinity of the studied area suggesting a distant source for the crystalline and quartz clasts. Their occurrence implies a continual activity of the fan delta yielding quartz clasts to subunit 1-1 although the type of deltaic system and the lithology of its source area might be changed. The presence of Paleogene clasts indicates erosion (cannibalism) of older basin fill deposits probably related to relative sea level fall. *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC found in the clasts are not of local origin; the closest area of their occurrence is nearby Zakopane (E. Köhler, personal comm. 1999, Fig. 1) implying efficient tranport by longshore currents.

The prevailingly massive conglomerates in the lower part of the succession are interpreted as deposits of cohesive debris flows (e.g. Nemec & Steel 1984, Mutti 1992, Nelson & Nilsen 1997). The frequent amalgamation and only minor occurrence of sandstone beds suggest erosional ability of flows. Better internal organization of conglomerate beds upward (normal and inverse grading) is thought to be a result of deposition from hyperconcentrated flows. The flows originated by dilution of cohesive debris flows by ambient water. The erosional ability of these flows was already low as shown by sharp bed bases and increased occurrence of separating sandstone beds. The traction and water-escape structures of sandstones indicate further flow transformation to high-density turbidites (e.g. Nemec & Steel 1984, Mutti 1992).

The black and blackish-brown shales with thick conglomerate and sandstone beds comprising subunit 2-2 are interpreted as basin slope and base-of-slope deposits. The shales were deposited from suspension clouds in a submarine slope (or steeply inclined ramp, Fig. 9) environment. The mean TOC content 0.7% suggests weak circulation and intensive input of organic matter.

The poor sorting, weak internal organization and sharp bases of thick conglomerate beds are indicative for deposits of cohesive debris flows (e.g. Hampton 1975, Reading & Richards 1994). Rare normal graded beds suggest dilution of the upper part of debris flows and generation of hyperconcentrated flows (e.g. Lowe 1975, Nemec & Steel 1984, Mutti 1992). The conglomerates probably originated by slope failures on shelf edge connected to relative sea level fall. The excess of sediments on the shelf edge may be partly connected to building of deltaic system feeding canyon fill of subunit 2-1.

The medium-grained massive sandstones (facies F5 of Mutti 1992, S3 of Lowe 1982) of subunit 2-2 are interpreted as high-density turbidity current deposits. The generation of these turbidity currents is also ascribed to slope failures on shelf edge during relative sea level fall. The compositional immaturity of sandstones implies that the sediments were derived from rapidly uplifted highlands and were not subjected to prolonged abrasion in a transitional, high-energy depositional setting such as beach, shoreface etc. It suggests a narrow, faulted shelf (e.g. Bruhn & Walker 1995).

The deposits of subunit 2-3, consisting of dark and black shales, thin sandstone beds and rare conglomerates, are thought to be deep-water deposits originated during relative sea level rise. The massive and faintly parallel-laminated shales were deposited from suspension clouds.

The occasional medium and fine-grained sandstones showing Bouma's T_{bcd} and T_{cd} divisions (facies F9 of Mutti 1992) were deposited by low-density turbidity flows. The rare massive conglomerates were probably deposited by debris flows generated by storms on shelf. The low frequency of sandstone and conglomerate beds implies decreasing activity of deltaic building.

Unit 3

The sandstone beds alternating with shales are interpreted as overbank deposits of a turbidite system. The inferred palaoeflow toward SE and E implies basin axial position of this system. Subunit 3-1, consisting of thin, laterally pinching out sandstone beds alternating with shales probably represents distal overbank deposits deposited by turbidite flows spilled over channel levee (e.g. Imperato & Nilsen 1990, Janočko et al. 1998). The very slow lateral thinning of beds suggests positive morphostructure of this part of a turbidite system. The higher frequency and increased thickness of sandstone beds of subunit 3-2, as well as abrupt pinching out, synsedimentary folds and starving ripples indicate deposition on levee slope closer to the channel.

The massive, sharply based conglomerates with massive and chaotic structures are interpreted as slump and debris flow deposits generating by slope failures. The occurrence of crystalline rocks in the clast composition suggest a constructive phase of deltaic building. The deposits of unit 3 are thought to be originated during relative sea level fall.

Implication for basin history

The composed sedimentary succession in the region of Spišská Magura consists of basal breccias and conglomerates overlain by nummulitic sandstones and limestones (unit 1) which are, in turn, overlain by coarse-grained canyon fill deposits (subunit 2-1), shales with thick conglomerate and sandstone beds (subunit 2-2) and shales containing thin sandstone beds (subunit 2-3). The whole succession is capped by alternating shale and sandstone beds (unit 3, Fig. 2). Based on biostratigraphy, the age of the succession is ranging from the Late Bartonian to the Early Rupelian.

The lowermost deposits of unit 1 were deposited during marine transgression and represent transgressive systems tract (Fig. 9). The first marine incursion to the studied region is assumed to be from the W, NW and N (Gross et al. 1980, 1993). The conglomerates prevailingly consisting of carbonate clasts suggest rugged coastal relief gradually destructed by marine erosion. A minor amount of the conglomerate clasts is composed of quartz from distant source area. The occurrence of quartz and the conglomerates separated by sandstones imply depositional system of a fan delta on a high-gradient shelf. However, the more intensive deltaic deposition was probably suppressed by rising sea level.

The coarse-grained deposits of subunit 2-1 and shales with conglomerates and sandstones of subunit 2-2 are thought to be deposited during relative sea level fall representing a lowstand systems tract (Fig. 9). The clast composition of the conglomerates suggests several sources and input of sediments by both deltas and longshore currents. The occurrence of clasts composed of older Paleogene rocks (Bartonian, P 14 zone indicated by *Nummulites brongniarti* D'ARCHIAC and *Nummulites puschi* D'ARCHIAC which are not common in basal deposits of the studied region) implies an important role of tectonics in the basin evolution which probably was the main factor triggering the change of relative sea level in the basin at that time. The basal deposits of unit 1 representing transgressive systems tract should be located on the basin margin and all the older Paleogene deposits should be located more basinward, thus stratigraphically below them. If the sea level fall during the deposition of subunits 2-1 and 2-2 was induced by eustatic sea level fall we should first expect erosion of the unit 1 deposits and only after then erosion of older Paleogene deposits. The clasts composed of Bartonian rocks in the canyon fill and conglomerate bodies of subunit 2-2 suggest tectonic uplift of some basinal parts composed of older Paleogene deposits which became source areas for canyon fill deposits and subunit 2-2 conglomerates. According to Maršalko and Radomski (1960) the palaeoflow was toward N indicating lateral sediment input into the basin.

The shales of subunit 2-3 reflect deposition in a quiet, low-energy environment during rise of sea level. The occasional thin beds of sandstones represent low-density turbidites probably generated by storms on shelf.

The gradual transition to the unit 3, interpreted as turbidite system deposits, suggests lowering of relative sea level. The nanoplankton from these deposits was mostly assigned to the nanoplankton zones NP 20-21 suggesting building of this turbidite system on the boundary between Eocene and Oligocene. The palaeoflow direction was parallel to the basin axis and oriented toward SE and E.

The main processes involved in formation of sedimentary succession are sea level variations , tectonics, sediment supply and climate (Rasmussen 1997). Comparison of the sea level curve inferred from our research to the eustatic sea level for Middle and Late Eocene and Early Oligocene (according to Abreau & Anderson 1998) shows little match (Fig. 9) suggesting that the eustatic sea level variation was not the main trigger responsible for the sedimentation in the investigated part of the CCP Basin. Similarly the climate during the Late Eocene and Early Oligocene was stable (Brinkhuis 1994) and probably did not influenced the sedimentation. It seems that the most important factor influencing sedimentation was the tectonic activity. It controlled basin size and shape, canyon floor gradient, shelf width and local relative sea level (e.g. Stow et al. 1985, Mutti & Normark 1987) determining the type of sedimentation and resulting sedimentary succession.

Conclusion

The sedimentary fill of the northern Slovak part of the CCP Basin (Spišská Magura region) consists of three

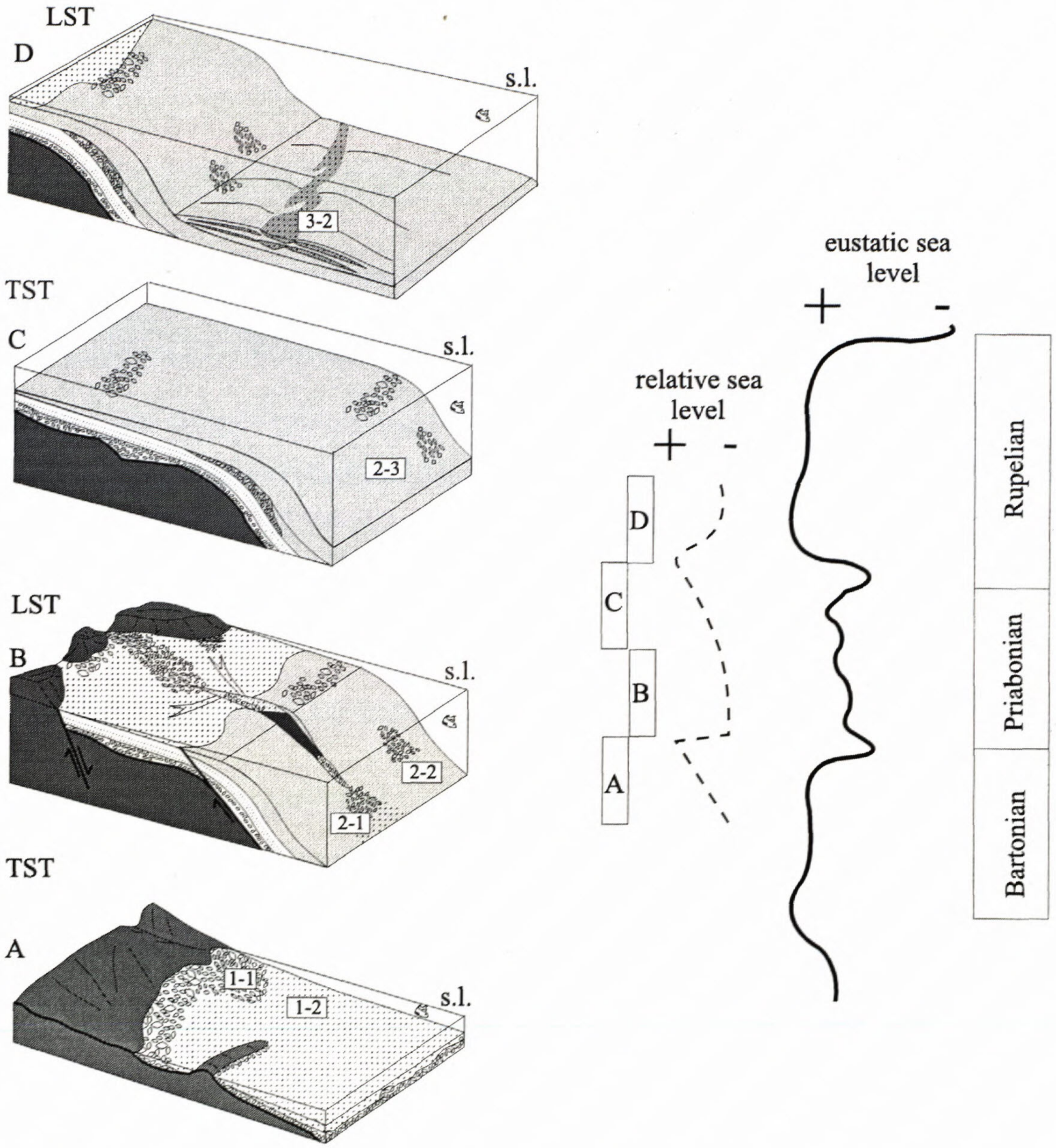

Fig. 9: Blockdiagrams showing development of the studied deposits in a time succession and comparision to the inferred and eustatic sea level curve. The eustatic sea level curve after Abreu and Anderson 1998. LST - lowstand systems tract, TST - transgressive systems tract. The arrows in the blockdiagrams B and D show the main palaeocurrent directions.

main lithologic units (Fig. 2) reflecting the basin sedimentary and tectonic history:

- Unit 1 consisting of basal breccias, conglomerates and nummulitic sandstones and sandy limestones;
- Unit 2 consisting of coarse-grained canyon fill, shales with thick conglomerate and sandstone beds and shales with thin sandstone and occasional conglomerate beds;
- Unit 3 consisting of alternating shale and sandstone beds

The age of unit 1 ranges from the Late Bartonian to the Priabonian based on nummulites analyses (planktonic foraminifera zones P14-P15). The age of units 2 and 3 is constrained by nanoplankton zones NP 17 –21 (Bartonian – Rupelian). The redeposited large foraminifera in the unit 2 deposits indicate early and middle Priabonian age (P 15 – P 16 zones). The occurrence of redeposited large foraminifera in the unit 3 deposits suggest early to late Priabonian age (P15 – P 17 zones).

Unit 1 was deposited during marine transgression in the Late Bartonian and Priabonian and represents transgressive systems tract. The sedimentation occurred on relatively steeply inclined shelf.

Unit 2 is composed of three subunits. The coarse-grained deposits of subunit 2-1 and shales with thick conglomerate and sandstone beds represent the lowstand systems tract. The relative sea level fall during this phase is mainly assigned to the local tectonic activity. The subunit 2-3 consisting of shales with thin sandstone and conglomerate beds represents the transgressive systems tract.

Unit 3 is composed of alternating sandstone and shale beds and represents the lowstand systems tract. The deposits are part of the basin axial turbidite system.

The timing and environmental interpretation of the studied deposits provides some new knowledge on the CCP Basin history. The most important determinant governing the sedimentation seems to be tectonics. We also suggest that the shales of subunit 2-2 does not necessarily represent a deep water deposition during one sedimentation cycle as assumed so far (e.g. Baráth et al. 1997, Buček et al. 1998). We did not find any striking evidence of an abrupt basin subsidence (often termed as a collapse) neither in the studied area of the CCP Basin nor in the neighbouring area of the Tatras where a continual succession of Mesozoic rocks can be found. Contrarily, we think that the subunit 2-2 shales may represent deposition during lowstand of relative sea level. However, our interpretation is still preliminary and we need further regional data to support our study.

Acknowledgement

This research was supported by the Ministry of Environment of the Slovak Republic and Norsk Hydro a.s. Norway. We thank Drs. Pavel Gross and Eduard Köhler for fruitful discussions on the deposits of the CCP Basin. Drs. Luis Pedro Fernandez and Eduard Remacha reviewed the manuscript and suggested many improvements. To all these institutions and persons we extend our most sincere thanks.

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