Click to see slides from oral presentation

EA Sedimentary Environments of the Oligocene Krosno Beds: A New Interpretation in the Polish Outer Carpathians*

Piotr S. Dziadzio[1], Roger Higgs[2] and Arkadiusz Drozd[1]

Search and Discovery Article #11350 (2020)**
Posted October 5, 2020

*Adapted from extended abstract based on oral presentation given at 2019 AAPG Europe Regional Conference, Paratethys Petroleum Systems Between Central Europe and the Caspian Region, Vienna, Austria, March 26-27, 2019
 DOI:10.1306/11350Dziadzio2020

[1]Oil and Gas Institute-National Research Institute, Kraków, Poland (dziadzio@inig.pl)
[2]Geoclastica Ltd., Cornwall, United Kingdom

Introduction

This article presents a new concept of the tectonic and depositional environment of the Menilite-Krosno Beds classic flysch deposits (Dżułyński et al., 1959; Książkiewicz, 1975, 1977) in the Polish Outer Carpathians (Figure 1). The Menilite Beds and the overlying Krosno Beds, both historically interpreted as deep-marine deposits, are here reinterpreted as shelf deposits of a large lake, occasionally ocean-connected, which may have resulted in fully marine conditions at times. The new depositional model proposed here is based on the discovery of abundant wave-formed sedimentary structures (recently, farther west, the Magdalena Sandstone Member of the Menilite Beds has been reinterpreted as shelfal rather than deep; Dziadzio et al., 2016) and on paleogeographic reconstructions by Rögl (1999) for Early Oligocene and Early Miocene times (corresponding essentially to the Menilite-Krosno Beds) which show that the Carpathian region was within a large enclosed water body, a remnant of the formerly through-going Paratethys seaway, isolated from the world ocean for much of Oligo-Miocene time, forming a freshened sea or giant lake (Vakarcs and Magyar, 2004) here named “Lake Krosno”, a hydrologically open remnant-ocean lake trapped in a long collision belt at an early stage of collision, evolved from the Paratethy seaway. The great majority of Menilite-Krosno sand beds are interpretable as hyperpycnites and wave-modified hyperypcnites, supplied by rivers, mainly longitudinally from the west.

New Depositional Model of the Krosno Beds

Like all foreland flysch (also known as miogeosynclinal flysch as opposed to eugeosynclinal flysch; see discussion and references in Higgs, 2014), the Menilite-Krosno Beds are characterized by bed ‘packeting’, i.e. alternating packets, generally 1-30 m thick, of thinner (mm or cm) and thicker (usually cm or dm) event beds, attributable to eustatic sea-level oscillations transmitted over the lake sill (Hiss, 1991, 2014, 2017).

Evidence for shelfal sedimentary conditions includes the following sedimentary structures and compositional attributes: hummocky cross stratification (HCS); pot casts (“whirls balls” of Dżułyński et al., 1957); gutter casts; symmetrical ripples (including vortex ripples); near-symmetrical ripples (indicating a combined flow comprising a one-way sediment-supplying current accompanied by a wave-induced oscillatory flow); interference ripples (symmetrical or near- symmetrical); sinusoidal lamination (rounded, symmetrical or near-symmetrical ripples climbing vertically or near-vertically); multidirectional tool marks; hooked grooves; non-orthogonal (to nearly parallel) ripple crests and sole marks on the same event-bed; and conspicuous muscovite and terrigenous plant matter mostly present in fine and very-fine sandstone beds interpretable as hyperpycnites (see below and Zavala et al., 2011, 2012). No evidence of subaerial conditions has been found. There is also no evidence of sedimentation in the beach/coast zone and no tidal structures were seen, although west of the research area such structures (tidal rhythmites) have been described in the uppermost part of the Menilite Beds (Dziadzio, 2018, in press).

There is also evidence for low salinity (brackish or fresh) and for reduced bottom oxygenation of the Menilite-Krosno Basin (Lake Krosno). These are: low diversity of fossils (benthonic megafossils) and trace fossils (see Książkiewicz, 1977); low degree of visible vertical bioturbation; scarcity of pyrite (cf. Berner and Raiswell, 1984); presence of syneresis cracks; the nature of benthonic foraminifera (Książkiewicz, 1975, 1977), dominating in the older horizons, which almost completely disappeared and were replaced by calcareous types in the Krosno Beds (an additional possible factor is soupy bottom-mud due to low salinity). The Menilite-Krosno scarce benthonic-foram fauna comprises both agglutinated and calcareous genera (Książkiewicz, 1975). However, it differs strongly from the “flysch-type agglutinated fauna” composed entirely or mainly of agglutinated taxa, characteristic for eugeosynclinal flysch (Higgs, 2014). Mixed agglutinant-calcareous faunas like that of the Menilite-Krosno Beds typify miogeosynclinal flysch (Higgs, 2014). Higgs (2014) suggested that these faunas are only “pseudo-bathyal” (“false bathyal” of Higgs, 2017a), being misinterpreted as bathyal due to a misleading combination of: (a) reworking of true deep-water taxa from adjacent accretionary-wedge mountains, and (b) dysoxia of flysch-shelf bottom-mud (i.e. fairweather) due to permanent lake-water stratification.

A possible explanation for low diversity of trace fossils and scarcity of vertical ones is that Lake Krosno salinity for much of the time was low (brackish or fresh), rendering the bottom-mud weakly cohesive (characteristic of open lakes, cf. Higgs, 1991) and therefore (?) exceptionally watery (soupground or perhaps ultra-soupground), detrimental to the visibility of burrows (very strongly compressed by compaction; cf. Schieber, 2014) and unfavorable in the first place for many types of burrowing animals.

The vast majority of sandstone event-beds in the Menilite-Krosno Beds can be interpreted as hyperpycnites and wave-modified hyperypcnites (rather than the near-universally assumed slump-generated turbidites), supplied mainly longitudinally by sediment-laden rivers. Based on all of the above: (a) these sandstone beds were probably deposited on a shelf (i.e. the feeder-delta slope may have been too low/short for slumps to evolve into turbidity currents), and (b) lowered salinity (very prone to hyperpycnal flow; see below) occurred for much of the time, especially during lowstands, corresponding to the thicker-bedded packets.

Thus, most sandstone beds in the Menilite-Krosno Beds can be interpreted as wave-modified hyperpycnites with HCS and/or other wave-formed sedimentary structures (see Higgs, 1991, Myrow et al., 2002). Those sandstone beds capped by ripple cross lamination and (slightly) asymmetrical ripples are habitually assigned to the Bouma Tc division, implying unidirectional flow. However, combined-flow ripples (i.e. near-symmetrical ripples) and corresponding cross lamination differ only subtly from their unidirectional-flow counterparts (e.g. Harms, 1969;

Higgs, 1984; Myrow et al., 2002) and have hitherto been overlooked in the Menilite-Krosno Beds, as have the truly symmetrical ripples. Each such sandstone bed can be interpreted as the product of a flood event accompanied by a storm, resulting in a wave-modified hyperpycnite with HCS and/or other wave-formed sedimentary structures (cf. river-fed wave-modified turbidites of Myrow et al., 2002; Pattison, 2005).

It is this combination of eustasy, early collision in a very long (>1,000 km) collision belt, floods and storm waves that explains the unique character of foreland flysch, including the Menilite-Krosno Beds (i.e. packeted; entirely shelfal; few or no intervals with fully marine fauna) by generating five specific controlling factors: (1) a low-salinity lake, that by definition is (2) very prone to hyperpycnal flow, both during floods and fair weather (rivers need more than fifty times more suspended sediment to underflow the sea compared to a freshwater lake; Mulder and Syvitski, 1995), hence (3) massive fluvial-sediment transfer directly to the shelf, greatly slowing the (bypassed) delta's progradation onto the shelf, (4) storm-wave 'shaving', limiting shelf aggradation, maintaining the shelf's intrinsic equilibrium profile (Higgs, 2010, 2014), and (5) fluctuations in water depth and brackishness by glacioeustatic incursions over the lake sill (Higgs, 1991), the rapidity of these eustatically driven lake-level rises and falls causing the trademark bed-packeting of foreland flysch (Higgs, 2014, 2017).

Conclusions

All of these facts strongly suggest deposition of the Menilite-Krosno Beds on the shelf (i.e. between storm- and fair-weather wave base) in a vast remnant-ocean lake, called here "Lake Krosno", evolved from Paratethys. The low salinity of the basin (lake) justifies the interpretation of the majority of sandstone beds as hyperpycnites. The shelf equilibrium profile governed by storm erosion, intrinsic to all shelves, limited sediment aggradation, while delta progradation was slowed by the lake's low salinity favoring delta bypass by hyperpycnal flow, delaying the eventual overrunning of the shelf by deltaic deposits (Higgs, 1991, 2014, 2017).

Acknowledgements

The authors would like to thank Polish Oil and Gas Company (POGC) for permission to publish the results of research on the Krosno Beds. Project financed by POGC.

Selected References

Berner, R.A., and R. Raiswell, 1984, C/S method for distinguishing freshwater from marine sedimentary rocks: Geology v. 12, p. 365-368.

Ciurej, A., and G. Haczewski, 2012, The Tylawa Limestones – a regional marker horizon in the Lower Oligocene of the Paratethys: Diagnostic characteristics from the type area: Polish Geological Institute, Geological Quarterly, v. 56, p. 833-844.

Dziadzio, P.S., I. Matyasik, M. Garecka, and A. Szydło, 2016, Lower Oligocene Menilite Beds, Polish Outer Carpathians: Supposed deep-sea flysch locally reinterpreted as shelfal, based on new sedimentological, micropalaeontological and organic-geochemical data: Oil and Gas Institute - National Research Institute, Kraków, Monograph 213, 120 p.

Dziadzio P.S., 2018, Sedimentary environment of the Menilite Beds in the Stróże Thrust Sheet, Silesian Unit, Carpathians: Nafta-Gaz. No. 11 (in press).

Dżułyński, S., A. Radomski, and A. Ślączka, 1957, Sandstone whirl balls in the silts of the Carpathian-flysch: Annales Societatis Geologorum Poloniae, v. 26, p. 107-129.

Dżułyński, S., and A. Ślączka, 1959, Directional structures and sedimentation of the Krosno Beds (Carpathian flysch): Annales Societatis Geologorum Poloniae, v. 28, p. 205-260.
Haczewski, H., 1989, Coccolith limestone horizons in the Menilite-Krosno Series (Oligocene, Carpathians) − identification, correlation and origin: Annales Societatis Geologorum Poloniae, v. 59, p. 435-523.
(in Polish, with English summary.)

Harms, J.C., 1969, Hydraulic significance of some sand ripples: Geological Society of America Bulletin, v. 80, p. 363-396.

Higgs, R., 1984, Possible wave-influenced sedimentary structures in the Bude Formation (Lower Westphalian, south-west England), and their environmental implications: Proceedings of the Ussher Society 6, p. 88-94.

Higgs, R., 1991, The Bude Formation (Lower Westphalian), SW England: Siliciclastic shelf sedimentation in a large equatorial lake: Sedimentology, v. 38, p. 445-469.

Higgs, R., 2010, Why do siliciclastic shelves exist? How do they differ from “ramp margins?” New sequence stratigraphic aspects vital for petroleum exploration: AAPG/Datapages Search and Discovery Article #40527 (2010).

Higgs, R., 2014, Shelf model for “deep-sea” flysch turbidites and implications for outcrop analogs: AAPG/Datapages Search and Discovery Article #70157 (2014).

Higgs, R., 2017, Reinterpreting the paleosalinity and water depth of peripheral foreland basin flysch: AAPG/Datapages Search and Discovery Article #30508 (2017).

Książkiewicz, M., 1975, Bathymetry of Carpathian Flysch Basin: Acta Geologica Polonica, v. 25, p. 309-367.

Książkiewicz, M., 1977, Trace fossils in the flysch of the Polish Carpathians: Palaeontologica Polonica, v. 36, p. 1-208.

Mulder, T., and J.P.M. Syvitski, 1995, Turbidity currents generated at river mouths during exceptional discharges to the world oceans: Journal of Geology, v. 103, p. 285-299.

Myrow, P.M., W. Fischer, and J.W. Goodge, 2002, Wave-modified turbidites: combined-flow shoreline and shelf deposits, Cambrian, Antarctica: Journal of Sedimentary Research, v. 72, p. 641-656.

Pattison, S.A.J., 2005, Storm-influenced prodelta turbidite complex in the lower Kenilworth Member at Hatch Mesa, Book Cliffs, Utah, U.S.A.: implications for shallow marine facies models: Journal of Sedimentary Research, v. 75, p. 420-439.

Rögl, F., 1999, Mediterranean and Paratethys - Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview): Geologica Carpathica, v. 50, p. 339-349.

Schieber, J., 2014, Traces in the dark − sedimentary processes and facies gradients in the Upper Devonian - Lower Mississippian upper shale member of the Bakken Formation, Williston Basin, North Dakota, U.S.A. – discussion: Journal of Sedimentary Research, v. 84, p. 837-838.

Vakarcs, G., and I. Magyar, 2004, Freshened seas or giant lakes: Eustacy and history of the Paratethys: AAPG/Datapages Search and Discovery Article #90034.

Zavala, C., M. Arcuri, and L.B. Valiente, 2012, The importance of plant remains as diagnostic criteria for the recognition of ancient hyperpycnites: Revue de Paléobiologie, Genève, v. 11, p. 457-469.

Zavala, C., M. Arcuri, H. Gamero Diaz, C. Contreras, and M. Di Meglio, 2011, A genetic facies tract for the analysis of sustained hyperpycnal flow deposits, in R.M. Slatt and C. Zavala, eds., Sediment transfer from shelf to deep water-Revisiting the delivery system: AAPG Studies in Geology No. 61, p. 31-51.

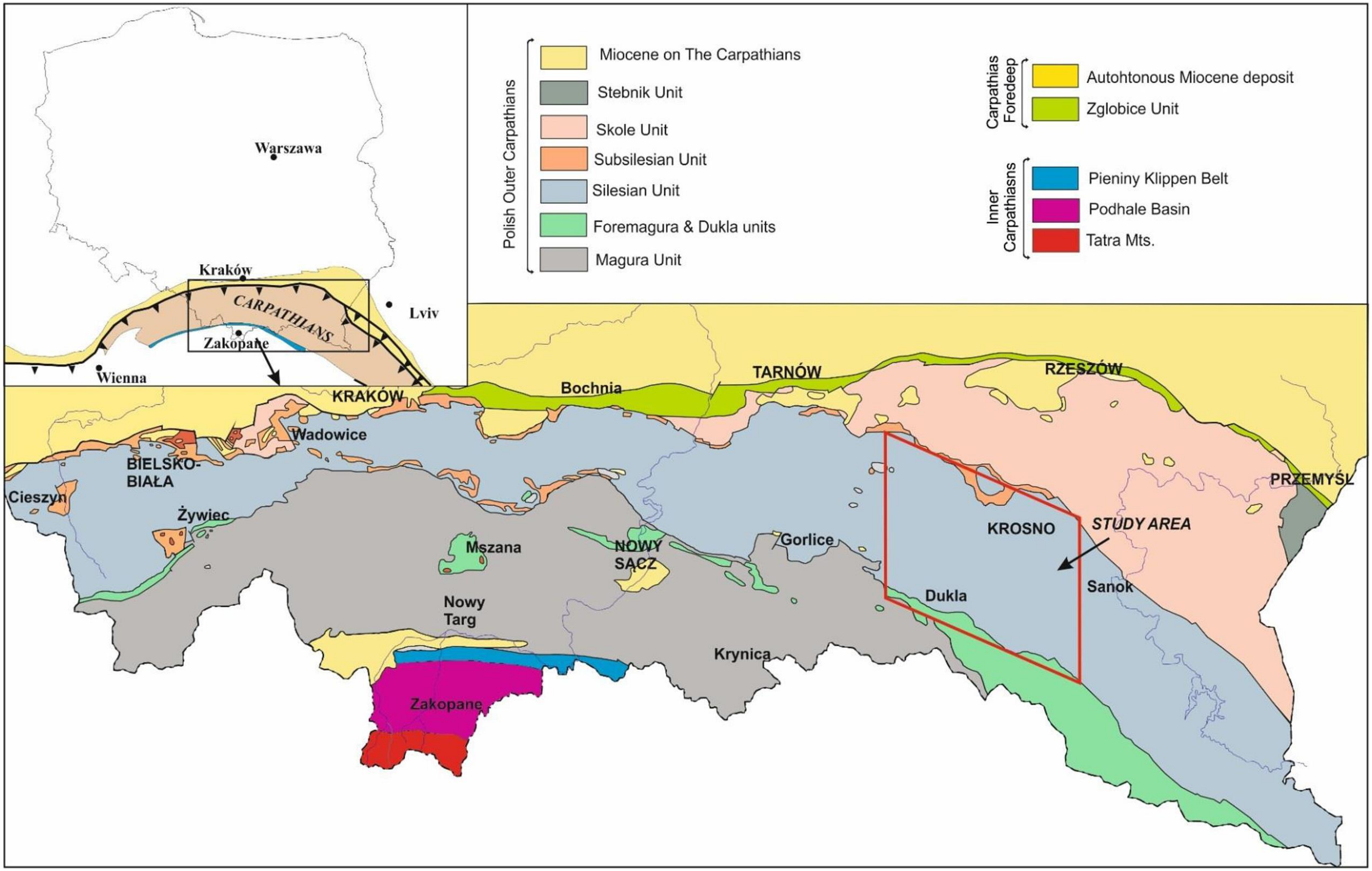

Figure 1. Location of the study area.