



## **Facies and provenance of deep marine sediment gravity flows with fragments of coalified land plants at Lipowica, the Cergowa Beds (Oligocene), Outer Carpathians of Poland**

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Facies analysis of the Cergowa Beds of the Polish and Slovak Outer Carpathians shows that this deep-marine siliciclastic unit was deposited by a spectrum of gravity flows ranging from high to low density, which deposited three facies associations (A, B and C). Association A consists of very fine- to medium-grained sandstones with mudstone and coal clasts, granules and rich in coalified organic matter fragments. Sandstones beds reach 8 m in thickness, are massive and subordinately parallel laminated (Ta and Tab). They are interpreted as resulting from incremental, rapid deposition from collapse of a near-bed layer (Ta, Tab) and laterally sheared near-bed layer (Tb) below high-density, turbulent flows and steady turbidity currents or, in case of mud-rich sandstones, en masse deposition by debris flows. Association B comprises very fine- and fine-grained sandstones with mud and coal clasts, granules and coalified plant fragments and detritus. They are massive, parallel- and ripple cross-laminated (Tab, Tabc, Tbc), reach 2 m in thickness and contain mudstone intercalations up to 50 cm. These sandstones seem to have originated from a combination of incremental deposition by high-density turbidity currents (Tab, Tb), low-amplitude bedload waves at the upper stage planar lamination in more dilute turbidity current (Tb) and suspension of fully turbulent and dilute turbidity currents (Tbc, Tc). Association C consists of very fine- to fine-grained sandstones and siltstones with fine organic detritus and minor mud clasts. Parallel- and ripple cross-lamination (Tbc, Tbcd) dominate, bed thickness of sandstones and siltstones amounts to 1-50 cm and mudstones reaches 200 cm. Association C was deposited by transformation of waning, dilute and fully turbulent turbidity currents from ripples into lower stage planar lamination.

Sandstone and mudstone beds at Lipowica (Poland) contain three types of coalified terrestrial organic matter. Based on their morphology and size these are: (i) coalified plant detritus dispersed in B and C associations, (ii) coalified plant fragments forming elongated lenses in A and B associations and (iii) coalified fragments of tree trunks occurring in A and B facies. Petrographic components of organic matter represented by collotelinite, telinite, gelinite and fusinite with co-occurring framboidal pyrite indicate terrestrial plants affected by fast gelification and burial processes of varying intensity. The size of the plant fragments supplied to the Dukla basin is positively correlated with indicators of hydrodynamic regimes suggested by their hosting

sediments. Namely, the larger the fragments, the higher flow energy and steadier and longer lasting sustained sediment delivery.

Sedimentary features of the Cergowa Beds suggest deposition out of gradually aggrading sustained turbulent sandy gravity flows primarily controlled by hyperpycnal effluents from a delta. Palaeocurrent data and comparison of mineral composition of sandstone infilling a hollow coalified tree trunk at Lipowica quarry with sandstone beds of the hosting succession suggest provenance from shelf fringing the emergent Silesian Ridge, which acted as a source area to the west of the basin. The depositional age NP23 and NP24 during the Oligocene eustatic sea-level fall implies that the delta supplying the Cergowa basin was located at the edge of this shelf.