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The influence of sedimentation and diagenetic processes on economic significance of the Cergowa sandstones from “Lipowica II-1” deposit

Introduction

The Cergowa sandstone (Lower Oligocene) occurs in two tectonic units of Polish flysch Carpathians (Cieszkowski et al. 1990). The south-western part of the Cergowa sandstone lithosome is situated in the area of the Dukla Tectonic Unit and the north-eastern part occurs in the south-eastern sector of the Silesian Tectonic Unit, referred to as the Pre-Dukla Unit (Fig. 1.1).

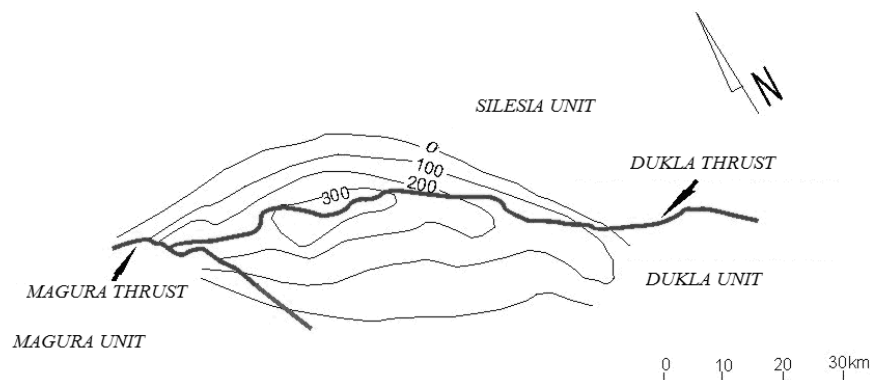


Fig. 1.1. Sketch of the Cergowa sandstone lithosome and its isopachytes (modified from Ślęczka, Unrug 1976)

Rys. 1.1. Szkic litosomu piaskowców cergowskich z miąższościami (Ślęczka, Unrug 1976), zmienione przez autora

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Initially, the Cergowa sandstones were described as sandstones of the menilite schists (Warchołowska-Pazdrowa 1929). The name Cergowa sandstones used to the present day was suggested by H. Teisseyre (1932). Separating this sandstone lithosome from the menilite strata, H. Teisseyre paid particular attention to its limited lateral extent and individual facies development. The unit name is derived from outcrops in the area of Mount Cergowa near Dukla. The Cergowa sandstones, especially in the south-eastern part of the occurrence area, are interbedded with the Cergowa shales (Fig. 5.1). The name Cergowa Beds (Series) is suggested for these two lithological elements (Ślączka 1971). Because of a substantial similarity in sediment development, thick-bedded sandstones and shales with bedded cherts of the Krosno Formation are considered equivalent to the Cergowa strata (Ślączka 1977). A characteristic interbed of the Tylawa Limestone that occurs in the Cergowa Beds (Ślączka 1971) is a regional correlation marker.

Cergowa sandstones are considered the most valuable, in industrial terms, industrial mineral of the Dukla and pre-Dukla Units and one of more important in that respect in the Carpathians. Highly valued technical properties of these sandstones are particularly related to their mineral composition, structural and textural features as well as diagenetic processes.

1. Description of the Cergowa sandstone development

A. Ślączka and R. Unrug (1976), one of few geologists working so far on the Cergowa sandstone aspects, present this unit as an elongated lithosome of south-west – south-east orientation (Fig. 1.1). This lithosome has a lenticular form in the longitudinal and transverse cross-section. The maximum thickness of about 350 m is reached in the central part and pinches out towards the margins (Fig. 1.1).

The Cergowa sandstones are usually thick bedded and contain interlayers of medium- and thin-bedded shales. Based on macroscopic observations the sandstones were defined as medium- and fine-grained with a small amount of coarse-grained material (Ślączka and Unrug 1976). Microscopic observations (Peszat 1984) enabled to define the discussed sandstones more precisely as mainly fine-grained and very fine-grained of sorting changing from poor to moderately good, and with the degree of sorting improving with decreasing grain size.

Rock fragments are the predominant component of the Cergowa sandstones and their proportion ranges between 24.8 and 58.4% (Table 1.1) (Peszat 1984). According to that author, sedimentary rocks, mainly carbonate, prevail among rock fragments (Table 1.1). Subordinate are grains of igneous (granitoids) and metamorphic (quartz-mica and gneiss schist) rocks. According to A. Ślączka and R. Unrug (1976) the proportion of quartz is 23–40% of all components. C. Peszat (1984) determines the amount of quartz as 20–36% (Table 1.1). Less common minerals are feldspars, the proportion of which does not exceed 10% (Table 1.1) (Ślączka and Unrug 1976, Peszat 1984) and micas, represented mainly by muscovite of average quantity below 11% (Table 1.1) (Peszat 1984). The other components,

TABLE 1.1.

Petrographic composition of the Cergowa sandstones (modified from Peszat 1984)

TABELA 1.1

Skład petrograficzny piaskowców cergowskich (Peszat 1984), zmienione przez autora

Components		Average percentage
Quartz		20,0–36,0
Feldspar		1,2–6,8
Mica		1,1–11,0
Grains of extraneous rocks		24,8–58,4
	Grains of carbonate rocks:	14,6–45,9
	Limestone	1,4–11,3
	Very fine and fine grained dolomite	2,0–13,0
	Medium grained dolomite	0,0–19,1
	Coarse grained dolomite	5,4–15,6
	Grains of sandstones and siliceous rocks	0,6–10,2
	Grains of shales	0,1–15,8
	Grains of granitoids and igneous rocks	0,2–6,4
	Grains of metamorphic rocks	0,8–5,3
Glauconite + organic detritus + heavy minerals		0,0–3,5
Cement		8,7–45,8

i.e. heavy minerals, glauconite, carbonised plant detritus and calcareous organic debris occur in accessory amounts. Their average proportion seldom exceeds 1% (Peszat 1984). The amount of cement, which has been determined as a dolomite-calcareous-clayey, is variable and ranges between 8.7 and 45.8% (Table 1.1) (Peszat 1984). The average amounts of individual components in the Cergowa sandstones enable to classify the rocks as grey-wackes. According to Pettijohn's classification, taking the proportion of cement into account, the Cergowa sandstones represent the class of lithic wacke and in subordinate cases – lithic arenite.

A variety of structural types may be distinguished among the Cergowa sandstones – massive, normally-graded, cross-laminated, parallel laminated and wavy laminated. C. Peszat (1984) observed relationships between these sedimentary structures and the grain size as well as the average proportion of individual mineral components. For example, sandstones showing graded or massive structure contain the coarsest grains. Parallel laminated sandstones contain the largest amounts of feldspar and mica. On the other hand, massive and normally graded beds contain more dolomitic rock fragments than the other bed types. Laminated sandstones contain the highest proportion of cement.

Erosional structures in the form of erosional channels and hieroglyphs (sole marks) are present on the bottom surfaces of the Cergowa sandstones. Sole marks are represented by flute casts, prod marks, skid marks, groove casts and longitudinal ridges (Ślaczka, Unrug 1976).

2. Environment of Cergowa sandstones sedimentation and diagenesis

The Cergowa sandstones lithosome is an example of a submarine fan deposited by turbidity currents and other sediment gravity flows (Ślaczka, Unrug 1976). These authors identified two zones within the Cergowa sandstones lithosome: the axial and the marginal zones. The axial part is characterised by coarser grain as compared with the other parts of the lithosome, by beds of higher thickness and the presence of structures indicating the upper flow regime. The margins and the distal parts of the axial zone contain material of finest grain (fine-grained sandstones), thin sandstone beds as well as structures characteristic of the lower flow regime.

The appearance and technical parameters of the Cergowa sandstones result primarily from diagenetic processes. C. Peszat (1984), based on microscopic examinations and chemical analyses, distinguishes a number of diagenetic transformations that occurred in the Dukla basin. Apart from diverse composition of lithic debris, small amounts of organic matter were deposited in the Cergowa sandstone basin (Ślaczka, Unrug 1976). The plant detritus was transported by turbidity currents together with clastic material into the environment of limited oxygen content, which is indicated by the presence of pyrite (Peszat 1984). The pyrite and particles of organic matter give the sandstone a bluish or greyish-blue colour. The Cergowa sandstones of such colour may be observed on non-weathered parts of outcrops. During field observations of the Cergowa sandstones, light-cream and brown colours are most often visible, resulting from weathering.

The processes, occurring during the diagenesis, were primarily related to dissolution (Peszat 1984). CO_2 was released during the organic matter decomposition at limited levels of oxygen. Small amount of carbon dioxide acidifying the environment resulted in the dissolution of carbonates. This way the pore waters were enriched with Ca^{2+} cations and with CO_3^{2-} ions. Pore waters of such chemical composition had a destructive effect on feldspars grains. The alkaline environment, originating this way, was favourable for quartz dissolution. In addition, the dissolution of the mineral grains was enhanced by the pressure resulting from compaction. The process of dissolution was so weak, that mainly the marginal parts of grains were damaged by corrosion. Despite low intensity this process was very important in the sediment's lithification. It increased the surface of the contact between the corroded grains and the cement. This resulted in a very strong cementation of the Cergowa sandstones, which is shown by their high hardness and resistance.

3. Palaeogeography of the Dukla unit

The Cergowa Beds are related primarily to the deposition area within the Dukla basin. Because of scarcity of the Lower Cretaceous formations in the Dukla unit, which are known from Ukraine (Ślączka 1971), it is assumed that the Dukla basin developed at the turn of the Lower and Upper Cretaceous, during the Austrian phase of the orogenic movements (Ślączka 1971, 1977). This basin, oriented in the north-west – south-east direction, was more than 250 km long and 70 km wide (Ślączka 1977). A. Ślączka (1971) situates the Dukla basin's position between the south-eastern border of Poland and the area situated in the vicinity of Smilno (Slovakia). Further on to the west this basin was most likely narrowing. M. Książkiewicz (1962) thought that to the west it was connecting with the fore-Magura basin. On the south, the Dukla basin was bounded by the Magura basin and on the north – by the Silesian basin. The borders between the basins consisted of submarine or emergent elevations (Ślączka 1971). At various stages the Dukla basing was more or less isolated from the neighbouring basins (Ślączka 1971). After the Dukla basin formation, in Lower Cretaceous, and also during the whole Palaeocene and part of Eocene, it remained isolated from the Silesian basin. During that period on the southern side, in particular in the Upper Cretaceous, it was connected with the Magura basin. The lack of a barrier between those two basins is indicated by a similarity in the development of the Łupków Beds and Cisna Beds of the Dukla Tectonic Unit as well as of Inoceramian Beds of the Magura Tectonic Unit. At the turn of Eocene and Oligocene, during the Pyreneean phase of the orogenic movements, there was a reconstruction of the Dukla basin (Ślączka 1971). At that time an elevated zone became clearly evident, isolating the Dukla basin from the Magura basin on the south, while the boundary with the Silesian basin on the north disappeared. After the Eocene-Oligocene reconstruction of the basin a change in the direction of clastic material transport occurred (Ślączka 1971). Up to that time the material was generally supplied from the south-east and from the east. The directional structures of palaeotransport in the Oligocene formations show that the transport occurred mainly from the north-west.

C. Peszat (1984) suggests that the non-carbonate detrital material forming the Lower Oligocene strata originated from the Silesian Cordillera. Most likely the carbonate material originated along the coastal zone of this cordillera. Microfacies represented by grains of limestone and dolomite document a low energy shallow-water environment, in a warm and dry climate (Peszat 1984).

4. Industrial importance of the Cergowa sandstones

The mineral composition of the Cergowa sandstones, characterised by a high content of carbonates, including dolomite grains, results in very favourable physico-mechanical properties (Bromowicz et al. 1976). So valuable technological parameters result primarily, in this case, from the presence of recrystallised carbonates. The sandstones show low and

moderate resistance to abrasion, low absorption and very high resistance to freezing and thawing (Bromowicz et al. 1976). These parameters enable to define this material as one of most valuable types among industrial Carpathian sandstone. Highly evaluated technical parameters of these rocks allow using them in the production of crushed aggregate, used mainly in the road and civil engineering and a part of the Cergowa sandstones, featuring poorer properties, are used in the road engineering at auxiliary works (Nieć et al. 2003).

The Cergowa sandstone is exposed in a 75 km long section, from the area of Nowy Żmigród to Żubracze (Nieć et al. 2003). In this area its mining was carried out so far in few quarries, inter alia in Komańcza, Lipowica and Żubracze. The mining of the Lower Oligocene sandstone is currently carried out in one quarry only, at Lipowica.

5. Mining of Cergowa sandstones using the example of Lipowica quarry

5.1. History of Lipowica quarry

In accordance with the information included in the geological documentation prepared for the Cergowa sandstones deposit “Lipowica II-1” (Nieć et al. 2003) the deposit of Cergowa sandstones in the area of Lipowica was documented for the first time in 1941 under the name of “Lipowica”. The place of raw material mining within this deposit consisted of a quarry situated a few kilometres south of Dukla, on the eastern slope of Mount Kielanowska. This open pit featured the strata dip close to the mountain slope inclination, the presence of shales interbedding the extracted thick-bedded sandstone and an unfavourable arrangement of joints (Górecki, Szwed 2004). These features accounted for the fact that the quarry was exceptionally predisposed to landslide generation. The mining operations were concluded in 1979 due to problems with the pit maintenance.

When a large landslide originated in the area of “Lipowica” deposit in 1970 and the mining became more and more difficult and costly, works were undertaken which resulted in 1975 in documenting a new deposit of the Cergowa sandstones (Nieć et al. 2003). The new deposit, named “Lipowica II”, was documented on the northern and southern slope of Mount Kielanowska. The southern part of “Lipowica II” deposit was opened and made available for mining in the years 1979–1982, which up to date operates as an open cast named “Lipowica”. The mining in this quarry is carried out now by Przedsiębiorstwo Produkcji Materiałów Drogowych Sp. z o.o. (Road Materials Production Enterprise, Ltd.) from Rzeszów, which holds a licence for the Cergowa sandstones mining valid by 2034. Efforts are made now to acquire new areas within the documented deposit and to expand the area covered by the mining (personal information E. Kusaj). By virtue of law the Cergowa sandstones from “Lipowica II-1” deposit is classified now as a common mineral (Nieć et al. 2003). It is used to produce crushed aggregate:

- graded key aggregate,
- graded aggregate,

- aggregate blends,
- ungraded aggregate,
- rock dust,
- crushed stone.

In accordance with the calculations presented in the geological documentation prepared for the Cergowa sandstones deposit “Lipowica II-1” (Niec et al. 2003) this deposit resources amount to around 18,350,000 tonnes, what makes 53% of commercial reserves of the whole “Lipowica II” deposit. Recent years witnessed substantial increase in the output. In 2008 the sandstone output amounted to 750,000 tonnes and the mining is planned to be increased to 1,000,000 tonnes (verbal information E. Kusaj).

The “Lipowica II-1” deposit is situated close to the area of protected landscape of the Beskid Niski mountains (Niec et al. 2003). In the vicinity of the open pit there is a forest preservation in Nowa Wieś, the Millennium Reserve on Mount Cergowa and Jasielski Landscape Park. This deposit is situated outside protected areas and far away from village and town settlement. Therefore, despite the fact that the deposit location is very attractive in terms of landscape, from the environmental point of view it is classified as a low-conflict deposit (Niec et al. 2003). The deposit’s definition as a low-conflict enables free activities related to the open pit expansion and to other works connected with this area land development. The mining works so far did not have a major impact on the surrounding environment (Niec et al. 2003). The deposit user plans to carry out reclamation towards forestation.

5.2. Structure of “Lipowica II-1” deposit

The “Lipowica II-1” deposit, situated on the southern slope of Mount Kielanowska, occurs within a overturned anticline, comprised by the fold of Mount Cergowa (Górecki, Szwed 2004). The axis of this anticline, of more or less S-N trending strike, follows the ridge of Mount Kielanowska. The axial surface of the overturned fold dips eastwards at an angle of around 58° (Niec et al. 2003). Because of asymmetric form of the saddle, the strata’s orientation on its both wings shows considerable variations. The eastern, upper wing, shows normal position of the strata. The western limb is overturned, with inverted beds dipping very steeply and sometimes vertically. The orientation of the overturned limb is close to the orientation of anticline’s axial surface. The greatest disturbance in the strata orientation and deformations are observed in the axial part of the anticline (Niec et al. 2003).

In the open cast mine situated in this structural context the mining is carried out along the line of Mount Kielanowska ridge (along the anticline axis) (Górecki, Szwed 2004). The only major hazards are rockfalls.

The described deposit is covered by forest and agricultural soils or clays. The thickness of the deposit overburden ranges from 0 to 3 metres (Górecki, Szwed 2004). The top parts of Mount Kielanowska feature no or small thickness of the overburden. The overburden becomes thicker on the mountain slopes, with decreasing altitude.

The “Lipowica II-1” deposit consists of sandstone interbedded with shale to various degrees. According to the data made available in the geological documentation (Niec et al. 2003), the most valuable part of the deposit is exposed in the eastern part of the quarry. It consists of thick-bedded sandstone, which in places is interbedded with very thin interbeds of shale (Fig. 5.1) proportion of which does not exceed 3–5% of the volume of this part of the deposit. In the remaining, smaller part of the open pit, medium- and thin-bedded sandstone are exposed and the proportion of the interbedded shales ranges from a few % to 90%. The average amount of shale interbeds within the whole deposit is estimated to be around 12%.



Fig. 5.1. Quarry “Lipowica II-1”. Coarse sandstones (Pg) and sandstones with shale interbeds (Pl) (photo by E. Kusaj)

Rys. 5.1. Kamieniołom „Lipowica II-1”. Piaskowce gruboławicowe (Pg) i piaskowce poprzelawicane łupkami (Pl) (fot. E. Kusaj)

Summary

Excellent physical characteristics, which make the Cergowa sandstones a demanded rock material, are the effect of mainly diagenetic processes. They resulted in the crystallisation of carbonate cement strongly binding the grains the surfaces or which were etched by the alkaline solutions. The facies development is the second key factor. As illustrated with the example of “Lipowica II-1” deposit, a thick-bedded sandstone, with a minimum proportion of shale interbeds, is the most valuable material. However, in the adjacent part of the same deposit, there occur much less attractive medium- and thin-bedded sandstones with substantial content of shale interlayers. Comparing these facies relationships with the trubidite

fan model, it is possible to suggest a preliminary interpretation that the “Lipowica II-1” deposit represents the mid-fan zone with a distributary channel filled with massive sandstone complex and the adjacent overbank is represented by deposits of shale and sandstone. Such approach suggests that a detailed sedimentological analysis may be an instrument used in forecasting zones interesting from the exploration point of view for the purposes of sandstone mining as the industrial mineral/crushed stone.

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REFERENCES

- Bromowicz J., Gucik S., Magiera J. i in. 1976 – Piaskowce karpackie, ich znaczenie surowcowe i perspektywy wykorzystania. Zeszyty Naukowe Akademii Górniczo-Hutniczej, Geologia t. 2, z. 2, 1–91.
- Cieszkowski M., Ślącza A., Zuchiewicz W., 1990 – Szczegółowa Mapa Geologiczna Polski 1:50000, arkusz Jaśliska. Państwowy Instytut Geologiczny.
- Górecki J., Szwed E., 2004 – Dokumentowanie geologiczne zagospodarowanych złóż kamieni budowlanych i drogowych na przykładzie złoża piaskowców w Lipowicy k. Dukli. Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej, nr. 108, 99–106.
- Książkiewicz M. (red.), 1962 – Atlas geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Kreda i starszy trzeciorzęd w polskich Karpatach zewnętrznych. Wydawnictwa Geologiczne, Warszawa, z. 13.
- Nieć M., Górecki J., Szwed E., 2003 – Dokumentacja geologiczna w kat. C₁ złoża piaskowców cergowskich „Lipowica II-1” (niepubl.), 1-28.
- Peszat C., 1984 – Zmienność składu petrograficzno-mineralnego piaskowców cergowskich na tle warunków ich depozycji i przemian diagenetycznych. Biuletyn Instytutu Geologicznego 346, t. 24, 207–234.
- Ślącza A., 1971 – Geologia jednostki dukielskiej. Prace Państwowego Instytutu Geologicznego, vol. 63, 1–77.
- Ślącza A., Unrug R., 1976 – Trends of textural and structural variation in turbidite sandstones: the Cergowa sandstone (oligocene, outer Carpathians). Rocznik Polskiego Towarzystwa Geologicznego, vol. 46, 55–75.
- Ślącza A., 1977 – Uwagi o budowie geologicznej Ziemi Krośnieńskiej. Jednostka Dukielska. Przewodnik XLIX Zjazdu PTG, Krosno, 22–25 września, Wydawnictwo Geologiczne, 13–30.
- Teisseyre H., 1932 – Zarys budowy geologicznej Karpat Dukielskich. Sprawozdania Polskiego Instytutu Geologicznego t. 7, z. 2, 319–336.
- Warchołowska-Pazdrowa O., 1929 – Budowa geologiczna okolic Dukli i Żmigrodu. Kosmos, r. 56, 3–4, 72–86.

THE INFLUENCE OF SEDIMENTATION AND DIAGENETIC PROCESSES ON ECONOMIC SIGNIFICANCE OF THE CERGOWA SANDSTONES FROM “LIPOWICA II-1” DEPOSIT

Key words

External Carpathians, crushed aggregate, Cergowa sandstones, sedimentation, diagenesis.

Abstract

The paper characterises the Lower Oligocene Cergowa sandstones, which form a lenticular lithosome within the Menilite Formation. The lithosome of the Cergowa sandstones classified as lithic wacke, represents sediments of a deep marine turbidite fan. Sedimentation and diagenetic processes had an essential influence on excellent physical parameters of this rock. A high hardness and resistance of the Cergowa sandstones is a result of thorough cementation with carbonate cement of grains corroded prior to lithification. A preliminary interpretation of two lithofacies, namely sandstone and sandstone interbedded with shale, mined in the "Lipowica II-1" deposit near Dukla, is presented in terms of the turbidite fan model. The author suggests that thick-bedded sandstones may represent mid-fan channel infills, while shale with sandstone interbeds may be an equivalent of facies deposited beyond the fan channels. It is suggested that sedimentological analysis, in this case based on the turbidite fan model, may be helpful in forecasting the occurrence zones of sandstones that possess the characteristics desired by the industrial minerals sector.

WPLYW PROCESÓW SEDYMENTACYJNYCH I DIAGENETYCZNYCH NA PRZYDATNOŚĆ GOSPODARCZĄ PIASKOWCÓW
CERGOWSKICH ZE ZŁOŻA „LIPOWICA II-1”

Słowa kluczowe

Karpaty zewnętrzne, kruszywa łamane, piaskowce cergowskie, sedimentacja, diageneza

Streszczenie

W artykule scharakteryzowano dolnooligocenyjskie piaskowce cergowskie, tworzące soczewę wśród warstw menilitowych. Litosom piaskowców cergowskich, sklasyfikowanych jako waki lityczne, reprezentuje osady głębokomorskiego stożka turbidytowego. Procesy sedymentacyjne i diagenetyczne wywarły zasadniczy wpływ na doskonałe parametry fizyczno-mechaniczne tych piaskowców. Wysoka twardość i odporność piaskowców cergowskich to efekt silnej cementacji spoiwem węglanowym ziaren, których powierzchnia uległa korozji przed zlitfikowaniem osadu. W kategoriach asocjacji facji turbidytowego stożka podmorskiego dokonano próby wstępnej interpretacji dwóch odmian litofacjalnych: piaskowcowej i łupkowo-piaskowcowej eksploatowanych w złożu „Lipowica II-1” koło Dukli. Autorka sugeruje, że piaskowce gruboławicowe mogą reprezentować osady kanałowe stożka środkowego, natomiast łupki z przeławiczeniami piaskowców mogą być odpowiednikiem facji pozakanałowych. Analiza sedymentologiczna, opierając się w tym przypadku na modelu turbidytowego stożka głębokomorskiego, może być pomocna w prognozowaniu stref występowania piaskowców o cechach pożądanych przez kopalnictwo surowców skalnych.