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SOURCE OF URANIUM IN THE ELBLĄG FORMATION (UPPER BUNTSANDSTEIN): SEDIMENTOLOGICAL APPROACH

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The Geological Institute subsurface studies on uranium mineralization in the Triassic of the Peribaltic Syneclize (2, 6 – 8) showed that the mineralization is the richest in the Elbląg Formation (*sensu* A. Szyperko-Śliwczyńska, 10). Drill cores from that formation have been covered by thoroughtful studies, within the frame of which the Author dealt with sedimentology of uranium-bearing sediments*. Sedimentological studies, preliminary results of which have been published in 1981 (5), made possible identification of the following sedimentary environments: braided rivers, meandering rivers, and shallow-water brackish basin with sandy barriers and shoals. A very similar interpretation was given by R. Strzelecki in 1985 (9).

The aim of this paper is to present further evidence supporting previously published hypothesis on source of uranium in the Elbląg Formation (5). The hypothesis has been put forward on the basis of results of sedimentological survey of area of typical development of the formation – the vicinities of Elbląg, or more precisely area between that town and Mierzeja Wiślana.

GENERAL SEDIMENTOLOGICAL CHARACTERISTICS

Fig. 1, showing key to sedimentological logs, may be also treated as some kind of list of the most characteristic features of the Elbląg Formation. The formation is terrigenous, made up of conglomerates, coarse- and medium-grained sandstones, fine-grained sandstones and sandy mudstones, mudstones and marls. The contribution of the latter is subordinate. Conglomerates are polymictic and almost completely structureless. Sandstones include arenites and wackes, represented by their lithic and arcosic varieties. Sandstones and sandy parts of conglomerates display horizontal lamination and current ripple lamination. Sediments of the formation are characterized by gray-green and brick-red to red colours and attain from 20 to 100 m in thickness (9, 10).

The list of features (Fig. 1) should be supplemented by the records of micro- and megaspores, agglutinated foraminifers, ostracods and fish scales in mudstones. Ostracods indicate brackish nature of the sedimentary basin. Attention should be paid to the scarcity of sedimentary structures (Figs. 2 – 6). This is due to the fact that Elbląg Formation rocks, especially sandy ones, are very poorly cemented, which makes sedimentological analysis of core material very difficult.

The above mentioned features of the deposits make it possible to draw the following conclusions:

1) the Elbląg Formation displays features typical of so-called red beds, most often interpreted as alluvial, lacustrine or eolian sediments;

2) red colour of sediments, presence of plant remains, and the lack of evaporites evidence hot, semiarid climate;

3) conglomerates and sandstones with sedimentary structures related to action of flowing waters, were formed in alluvial environment;

4) mudstones originated in result of deposition from

* In analyzing drill cores the Author used information and materials kindly supplied by R. Strzelecki, A. Szyperko-Śliwczyńska, E. Barejowa, and M. Sałdan, petrographic data of M. Nowicka, and micropaleontological data of T. Marcinkiewicz, O. Styk, and T. Orłowska-Zwolińska.

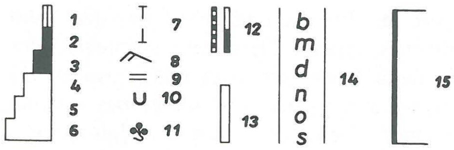

Fig. 1. Explanations of symbols used in Figs. 2–6.

1 – marls, 2 – mudstones, 3 – sandy mudstones, 4 – fine-grained sandstones, 5 – coarse- and medium-grained sandstones, 6 – conglomerates, 7 – vertical distribution of sedimentary structures, 8 – current ripple lamination, 9 – horizontal to slightly inclined lamination, 10 – bioturbations, 11 – coalified plant remains, 12 – scale bars (in meters), 13 – vertical extent of uranium mineralization, 14 – sedimentary environments: b – braided rivers, m – meandering rivers, d – deltas, n – nearshore zone and lagoons, o – offshore zone, s – sandy shoals and barriers; 15 – vertical range of Elbląg Formation.

Ryc. 1. Symbole użyte na ryc. 2–6.

1 – margle, 2 – mułowce, 3 – mułowce piaszczyste, 4 – piaskowce drobnoziarniste, 5 – piaskowce grubo- i średnioziarniste, 6 – zlepieńce, 7 – występowanie struktur sedymentacyjnych od – do, 8 – laminacja riplemarkowa, 9 – laminacja pozioma lub prawie pozioma, 10 – bioturbacje, 11 – zwęglone szczątki roślin, 12 – podziałki w metrach, 13 – pionowy zasięg mineralizacji uranowej, 14 – środowiska sedymentacji: b – rzek roztokowych, m – rzek meandrujących, d – delt, n – wód przybrzeżnych i lagun, o – wód odległych od brzegu, s – płycizn i barier piaszczystych; 15 – pionowy zasięg formacji elbląskiej.

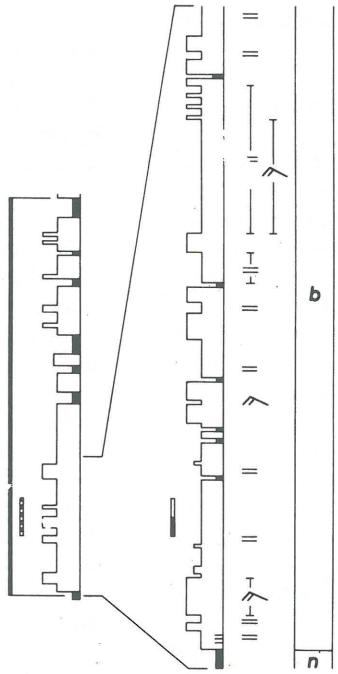

Fig. 2. Sedimentological log of the Elbląg Formation in the borehole Ptaszkowo IG-5.

Ryc. 2. Profil sedymentologiczny formacji elbląskiej w otworze wiertniczym Ptaszkowo IG-5.

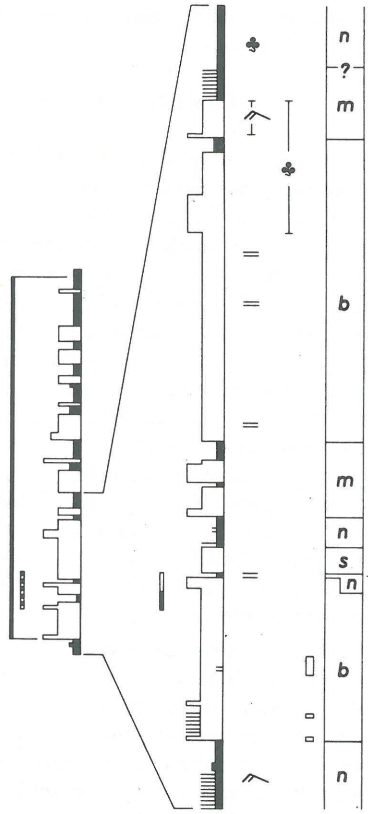

Fig. 3. Sedimentological log of the Elbląg Formation in the borehole Marianka IG-1.

Ryc. 3. Profil sedymentologiczny formacji elbląskiej w otworze wiertniczym Marianka IG-1.

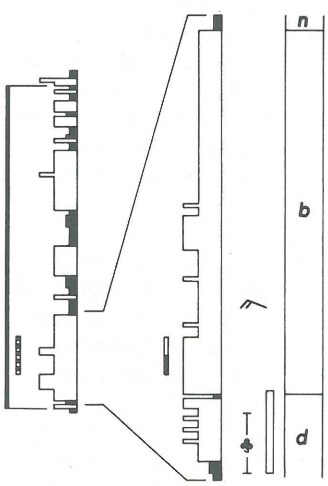

Fig. 4. Sedimentological log of the Elbląg Formation in the borehole Ptaszkowo IG-1.

Ryc. 4. Profil sedymentologiczny formacji elbląskiej w otworze wiertniczym Ptaszkowo IG-1.

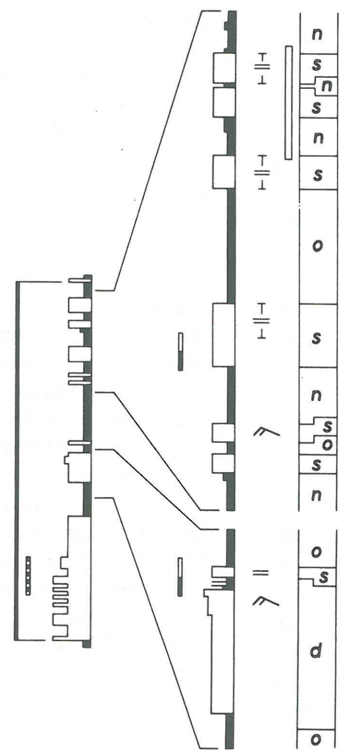

Fig. 5. Sedimentological log of the Elbląg Formation in the borehole Ptaszkowo IG-3.

Ryc. 5. Profil sedymentologiczny formacji elbląskiej w otworze wiertniczym Ptaszkowo IG-3.

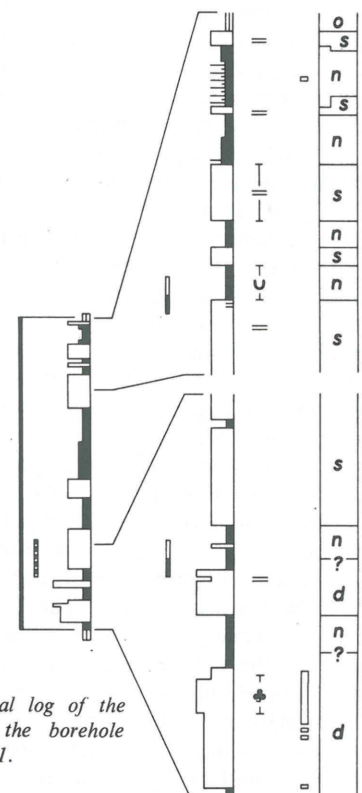

Fig. 6. Sedimentological log of the Elbląg Formation in the borehole Pasłęk IG-1.

Ryc. 6. Profil sedymentologiczny formacji elbląskiej w otworze wiertniczym Pasłęk IG-1.

suspension taking place mainly (but not exclusively) in brackish waters.

SEDIMENTARY ENVIRONMENTS

Fig. 2 shows sedimentological log of the Elbląg Formation from borehole situated in the northern part of the studied area. A simplified log of the whole formation (drawn on a smaller scale) clearly indicates its bipartity (cf. 10): its lower part consists almost exclusively of conglomerates and sandstones, and the upper – alternating sandstones and mudstones, with subordinate share of conglomerates. A fragment of the log, given in a larger scale, displays alluvial sediments interpreted as deposited by braided rivers. Sediments of that type form here sequences sometimes attaining over 50 metres in thickness. They are mainly represented by conglomerates and sandstones deposited in active braided river channels. Mudstones, sporadically found here, are interpreted as formed in abandoned channels. The recorded sedimentary structures include horizontal (upper regime) lamination and current ripple lamination.

Fig. 3 shows the next example of sediments of braided rivers. In that log, coming from southern part of the studied area, the sediments are rich in fine plant remains and horizontal lamination predominates. Attention should be paid to shows of uranium mineralization in lower part of the log, close to contact of braided river sediments and underlying interlaminated sandstones and mudstones representing nearshore part of brackish basin.

It should be noted that the Elbląg Formation sandstones interpreted as braided river sediments do not display large-scale cross-bedding, so common in such sediments. In accordance with physical model of sedimentation of alluvial sandy sediments (1), sandstones with horizontal lamination and small-scale cross-lamination indicate large curvature and small depth of river channel, and (in the case of sandstones displaying horizontal lamination only) relatively large water surface slope. This is in agreement with the view that these deposits originated in braided river environment.

A detailed log fragment (Fig. 3) also shows sediments of meandering rivers. Deposits of this type can only rarely be found. They appear as sequences 2 to 4 metres thick. The sequences are fining-upward. They consist of conglomerates, sandstones, and interlaminated sandstones and mudstones. The latter are interpreted as floodplain deposits. Most possibly conglomerates correspond to channel lag while sandstones are believed to represent point bar sediments. Top part of the detailed log displays possible transgressive muds formed in nearshore part of the brackish basin.

Fig. 4 shows other example of t :aided rivers sediments, from northern part of the stι died area. The characteristic bipartity of the Elbląg Formation is also clearly visible here: lower part of the formation is built of sandstones and conglomerates (mainly those of braided river environment), and the upper – alternating sandstones and mudstones of other sedimentary environments. A lower part of the detailed log demonstrates deltaic sediments. Attention should be paid to shows of uranium mineralization, marked across boundaries of different rock types. Another example of deltaic sediments from the same, northern part of the studied area, may be found in Fig. 5.

In the Elbląg Formation, deltaic sediments form coarsening-up-ward sequences comprising mudstones, interlaminated mudstones and sandstones, and sandstones, above which again mudstones and interlaminated mudstones and sandstones appear. These are sediments referable to prodelta, delta front and delta plain respectively. The coarsening-upward sequences are sometimes overlain by fining-upward ones. The latter consist of conglomerates, sandstones and mudstones. They are supposed to be formed in distributary channels. Channel sediments are missing in several deltaic sequences.

Deltaic sequences of the Elbląg Formation are 4 to 8 m thick. So small thickness indicates shallow-water character of the deltas.

A detailed log of upper part of the section from Fig. 5 shows nearshore, lagoon, sandy shoal and barrier, and offshore sediments. The latter are represented by mudstones, sometimes with thin sandy intercalations. The offshore sediments, varying from a few to about a dozen metres in thickness, are almost completely barren in organic remains, except for scarce coalified plant remains. Attention should be paid to shows of uranium mineralization in sandy barrier deposits and those of nearshore, lagoon part of the sedimentary basin. Here again the uranium mineralization cuts boundaries of different rock types.

Nearshore sediments are also shown in Fig. 6. This figure demonstrates sedimentological log of the stratotype section of the Elbląg Formation (cf. 10). The section has been revealed by borehole situated in southern part of the studied area. A detailed log of lower part of the stratotype section shows deltaic sequence overlain by transgressive nearshore sediments. It should be emphasized than uranium mineralization has been found in sediments of prodelta, delta front and possibly a distributary channel. Along with development of the transgression, sediments of sandy barriers and shoals shifted landwards over the nearshore sediments. Sediments of this type are also visible in upper part of the section (Fig. 6).

Deposits interpreted as representing sandy barriers and shoals include fine-grained sandstones, a few metres thick, interbedded with mudstones. The sandstones often display a parallel, almost horizontal lamination, responsible for their platy parting. Organic remains are practically missing here (except for occasional findings of coalified plant remains).

Nearshore and lagoon sediments are represented by mudstones and interlaminated mudstones and sandstones up to a few metres thick, with plant remains and agglutinated foraminifers. There also occur bioturbations of the feeding burrow type (Fig. 6) and, sometimes, calcareous nodules a few centimetres in size. The latter seem to reflect temporary emergence and onset of soil-forming processes. It is worth to note uranium mineralization in the interlaminated sandstones and mudstones interpreted as formed in nearshore part of the brackish basin (Fig. 6 – upper part of the log).

Interfingering offshore and nearshore sediments and those of shoals and barriers form specific sequences up to 70 m thick, mainly known from upper part of the formation.

PALEOGEOGRAPHY

Results of analysis of vertical succession of sediments, briefly discussed above (Figs. 2–6) gave the basis for construction of a model of sedimentation of the Elbląg Formation. This model shows interfingering of alluvial sedimentation with sedimentation in a vast brackish basin (Fig. 7). Sandy material and pebbles were mainly supplied

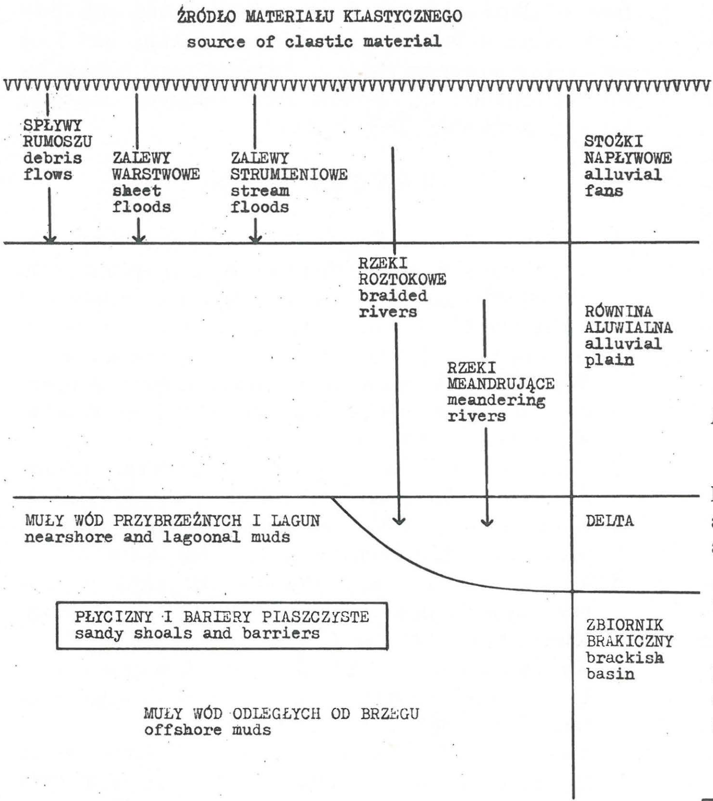

Fig. 7. Model of sedimentation of the Elbląg Formation.

Ryc. 7. Model sedymentacji formacji elbląskiej.

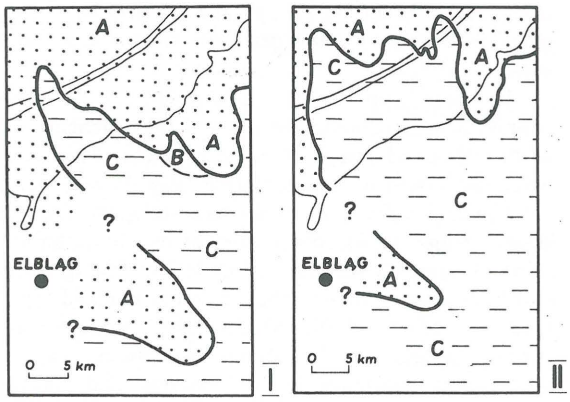

Fig. 8. Paleogeographic maps of the Elbląg Formation between Elbląg and Mierzeja Wiślana.

I – lower operational unit, II – upper operational unit, A – alluvial plain facies association, B – shallow-water delta facies association, C – facies association of brackish sedimentary basin.

Ryc. 8. Mapy paleogeograficzne formacji elbląskiej między Elblągiem a Mierzeją Wiślaną.

I – dolna jednostka operacyjna, II – górna jednostka operacyjna, A – asocjacja facjalna równiny aluwialnej, B – asocjacja facjalna płytkowodnej delty, C – asocjacja facjalna brakicznego zbiornika sedymentacji.

by a system of braided rivers. In accordance with classic models of sedimentation, alluvial sediments pass into those of alluvial fans along with decrease in distance from source areas. Alluvial fans have not been found in the studied area but it may be assumed that they are present farther to the north.

Three facies associations occur in the studied area (Fig. 7): alluvial plain, delta, and brackish basin association. The first of them comprises sediments of braided and, partly, meandering rivers, the deltaic association – those of prodelta, delta front and delta plain and, sometimes, distributary channels, and the brackish basin association – nearshore and offshore sediments, separated by those of sandy shoals and barriers.

The recorded organic microfossils make possible assignation of the Elbląg Formation to the Rhöt (*fide* 8) but appear insufficient for further biostratigraphic subdivision. Therefore, two arbitrary operational units were differentiated for construction of paleogeographic maps: lower and upper. Boundary between these units was arbitrarily drawn in the middle of thickness of the formation in all the studied borehole columns. For each operational unit in each of the sections studied, facies association dominant in thickness was found. Then symbols of dominant associations have been plotted on the map next to location points of the sections measured. Subsequently, boundaries of the areas of different facies associations have been drawn and paleogeographic map for a given operational unit has been obtained (Fig. 8). The maps of the two operational units were constructed for the area shown in Fig. 9.

The comparison of these maps showed that in the course of sedimentation of the Elbląg Formation there has taken place a regression, followed by transgression

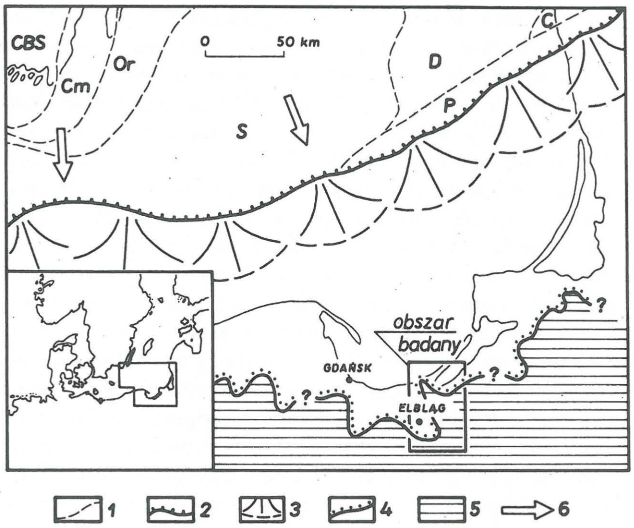

Fig. 9. Paleogeographic map of the Elbląg Formation in the Baltic coast area.

1 – extent of pre-Triassic rocks (cf. 3): CBS – crystalline rocks of Baltic Shield, Cm – Cambrian, Or – Ordovician, S – Silurian, D – Devonian, C – Carboniferous, P – Permian; 2 – extent of Lower Triassic sedimentary basin (cf. 10), 3 – alluvial fans, 4 – extent of conglomeratic-sandy sediments of alluvial plain (shallow-water deltas locally in the south), 5 – muddy and sandy sediments of brackish sedimentary basin, 6 – major directions of transport of clastic material.

Ryc. 9. Mapa paleogeograficzna formacji elbląskiej w obszarze nadbałtyckim.

1 – granice występowania skał przedtriasowych (por. 3): CBS – skały krystaliczne tarczy bałtyckiej, Cm – kambr, Or – ordowik, S – sylur, D – dewon, C – karbon, P – perm; 2 – zasięg zbiornika sedymentacji dolnego triasu (por. 10); 3 – stożki napływowe; 4 – zasięg zlepieńcowo-piaszczystych osadów równiny aluwialnej (na południu – lokalnie płytkowodne delty); 5 – mułowce i piaszczyste osady brakicznego zbiornika sedymentacji; 6 – główne kierunki transportu materiału klastycznego.

of brackich basin waters. In the studied area the transgression was proceeding generally from the south northwards.

The last step in the paleogeographic analysis was connected with attempt to draw a hypothetical extension of the obtained image in adjacent areas. This was made using the model of sedimentation (Fig. 7), after its adjustment to regional frames of the basin (Fig. 9). The obtained sketch image shows source area of clastic material in the north. Granitoid pebbles found in the Elbląg Formation conglomerates evidence that erosion reached crystalline basement of the Baltic Shield. The conglomerates also contain pebbles of limestones, dolomites, marls, claystones and quartzites from Paleozoic and older Buntsandstein deposits. The inferred zone of alluvial fans was stretching along the margin of that source area, and alluvial plain and brackich basin – farther to the south.

SOURCE OF URANIUM

As it was emphasized above, shows of uranium mineralization often cut boundaries of different rock types in the Elbląg Formation, which indicates their epigenetic nature (7). The major difficulty in explanation of origin of uranium from epigenetic sedimentary deposits is connected with the fact that its concentrations in such deposits are uncomparably higher than in the case of syngenetic disseminations. This requires assumption of erosion of gigantic rock masses in the neighbourhood (but outside the sedimentary basin) in the course of natural enrichment of the sediments in uranium (4). The question arising here is where such area may be found? The paleogeographic map from Fig. 9 gives fairly convincing answer. It shows that clastic material for the Elbląg Formation has been transported from the Baltic Shield in the north. Triassic erosion affected there both crystalline basement of the shield and sedimentary rocks at its margin, including the Cambrian. In the case of the latter, the Alum Shales are well known to be markedly enriched in uranium. Thus it seems quite probable that these shales acted as a source of uranium found in the Elbląg Formation. Groundwaters carrying uranium compounds were flowing to the south, i.e. in direction of original, sedimentary dip of alluvial sandy bodies. This process was presumably taking place in the end of Triassic as it may be assumed that synorogenic Early Cimmeric movements have resulted in uplift of northern marginal parts of the sedimentary basin and increase in southward dip of aquifers.

The most interesting shows of uranium mineralization are found in sandy-conglomeratic deltaic sediments (Figs. 4, 6). The shows found in conglomeratic-sandy bodies deposited by braided rivers (Fig. 3), sediments of sandy shoals and barriers and muddy-sandy sediments of nearshore part of the brackish basin (Figs. 5, 6) are less intense but also fairly interesting.

All the recorded shows of uranium mineralization are connected with conglomeratic-sandy or sandy sediments interbedded with mudstones. This is due to the fact that the Elbląg Formation has been formed along a regional front of alluvial-deltaic sediments interfingering with those of the brackish basin (Fig. 9). Along that front there have been active numerous reducing chemical traps, responsible for precipitation of uranium from solutions migrating through permeable sandy bodies.

REFERENCES

1. Allen J.R.L. – Studies in fluviatile sedimentation: a comparison of fining-upwards cyclothems, with special reference to coarse member composition and interpretation. J. Sedim. Petrol. 1970 vol. 40 no. 1.
2. Bareja E., Sałdan M., Strzelecki R. – Wstępne wyniki badań mineralizacji uranowej w utworach triasu w rejonie Krynicy Morskiej – Pasłęka. Kwart. Geol. 1980 nr 4.
3. Dadlez R. – Some geological problems of the Southern Baltic Basin. Acta Geol. Pol. 1974 no. 1.
4. Gabelman J.W. – Sedimentology and uranium prospecting. Sediment. Geol. 1971 vol. 6 no. 3.
5. Jaworowski K. – Warunki sedymentacji uranonośnych osadów triasu w syneklizie perybałtyckiej. Kwart. Geol. 1981 nr 4.
6. Kanasiewicz J., Sałdan M., Uberna J. – Uranonośność pstrego piaskowca okolic Pasłęka. Biul. Inst. Geol. 1965 nr 193.
7. Sałdan M., Strzelecki R. – Uranium in the Bunter Sediments of the Polish area. Ibidem 1980 nr 328.
8. Strzelecki R. – Wyniki badań mineralizacji uranowej w triasie syneklizy perybałtyckiej. Kwart. Geol. 1980 nr 4.
9. Strzelecki R. – O sedymentacji górnego pstrego piaskowca w syneklizie perybałtyckiej. Prz. Geol. 1985 nr 4.
10. Szyperko-Śliwczyńska A. – Trias dolny w północno-wschodniej Polsce. Pr. Inst. Geol. 1979 t. 91.

STRESZCZENIE

Z analizy sedymentologicznej wynika, że materiał klastyczny formacji elbląskiej transportowany był głównie rzekami roztokowymi, płynącymi z północy na południe (ryc. 9). Na obszarze tarczy bałtyckiej triasowa erozja objęła zarówno skały krystaliczne jak i pokrywę osadową. Najprawdopodobniej uran został uwolniony z erodowanych, kambryjskich łupków ałunowych Skandynawii. Związki uranu migrowały epigenetycznie poziomami wodonośnymi, zgodnie z pierwotnym (sedymentacyjnym) pochyleniem warstw północnego skłonu basenu sedymentacyjnego, tj. na południe. Proces ten miał miejsce zapewne w końcu triasu. Uran był strącany w redukcyjnych pułapkach chemicznych, występujących wzdłuż regionalnego frontu osadów aluwialno-deltowych, zazębiających się z osadami brakicznego zbiornika. Mineralizacja uranowa jest związana głównie z osadami płytkowodnych delt i rzek roztokowych.