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LITHOGEOCHEMISTRY OF UPPER FAMENNIAN-TOURNAISIAN STRATA IN THE OMOLON AREA (NE-USSR) AND ITS IMPLICATIONS

by

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(6 figures and 1 table)

ABSTRACT. - The geochemical distribution patterns of Mg, Sr, Na, Zn, Fe, Mn, K and IR (Insoluble Residue) of the Upper Famennian to Tournaisian strata in the eastern Omolon area have been analysed. For this purpose four localities were selected, namely Perevalny/Sikambr, Elergetkhyn, Pushok and Uljagan. The lithogeochemical patterns are to a large extent controlled by non-carbonate phases. Furthermore diagenetic processes such as dolomitization, recrystallization and dedolomitization also influenced the lithogeochemical patterns. Besides the patterns explained by non-carbonate phases and diagenesis, four lithogeochemical anomalies are present. The most important anomaly has a regional character and is suggested to be exhalative in origin. This Zn (Pb, Mn) anomaly occurs near the Devonian-Carboniferous boundary in the southern part of the studied Omolon area. Based on sediment-petrographic data it was shown that during this time-interval differential block-faulting occurred (Swennen *et al.*, 1986). A second anomaly developed in the Šikambr Formation of Perevalny/Sikambr. This Sr, (Zn) anomaly occurs in a sabkha sequence, therefore this anomaly seems to be facies-controlled. Since diagenetic crystallization may liberate an important amount of Zn, these metal-enriched solutions may have played a role in ore formation elsewhere. A third anomaly was found at the dolomitization front in Upper Famennian strata of Elergetkhyn. This Sr anomaly possibly is related to the dolomitization process, but diagenetic "shielding effects" of the intercalated shale beds may also have played a role. The fourth anomaly has a local character. Since this Pb, Mn anomaly was discovered along E-W trending faults in Perevalny valley, an epigenetic fault-related origin is favoured. It possibly indicates a potential for mineralizations of this type in the Perevalny valley.

RESUME. - Les modes de distribution du Mg, Sr, Na, Zn, Fe, Mn, K et IR (Résidu insoluble) ont été analysés dans les couches du Famennien supérieur et du Tournaisien de la région orientale de l'Omolon. Dans ce but, quatre localités ont été sélectionnées soit Perevalny/Sikambr, Elergetkhyn, Pushok et Uljagan. Les comportements lithogéochimiques sont contrôlés dans une large mesure par les phases non-carbonatées. De plus, des processus diagénétiques tels que la dolomitisation, la recristallisation et dédolomitisation ont influencé ces comportements lithogéochimiques. A côté des comportements expliqués par les phases non-carbonatées et la diagénèse, quatre anomalies lithogéochimiques sont présentes. L'anomalie la plus importante a un caractère régional et il est suggéré qu'elle est d'origine exhalative. Cette anomalie du Zn (Pb, Mn) apparaît près de la limite Dévonien-Carbonifère dans la partie méridionale de la région étudiée dans l'Omolon. Sur la base de données sédimentaires et pétrographiques, il a été démontré (Swennen *et al.*, 1986) qu'une tectonique de bloc failllé différentielle a existé à ce moment là. Une deuxième anomalie s'est développée dans la Formation Sikambr de la coupe Perevalny/Sikambr. Cette anomalie du Sr (Zn) apparaît dans une séquence de "sabkha" et semble donc être contrôlée par le faciès. Comme la cristallisation diagénétique peut libérer des quantités importantes de Zn, ces solutions enrichies en métal, peuvent avoir joué un rôle dans la formation des gisements ailleurs. Une troisième anomalie fut trouvée au front de dolomitisation dans les couches du Famennien supérieur à Elergetkhyn. Il est possible que cette anomalie du Sr soit liée au processus de dolomitisation mais des

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"shielding effects" diagénétiques du schiste intercalé peuvent aussi avoir joué un rôle. La quatrième anomalie a un caractère local. Puisque cette anomalie du Pb, Mn a été découverte le long de failles à alignements E-W dans la vallée de Perevalny, une origine liée à des failles épigénétiques est probable. Il est possible qu'elle indique un potentiel de minéralisations de ce type dans cette vallée.

1. - INTRODUCTION

The lithogeochemistry of carbonate rocks is frequently considered as an additional tool for obtaining information about their sedimentary environment or diagenesis, and also for evaluating the potential of Pb-Zn mineralizations. However, the interpretation of lithogeochemical distribution patterns is practically impossible without a thorough knowledge of the sediment petrography. Furthermore a detailed biostratigraphic framework is needed for correlation of individual sections and for the recognition of stratabound anomalies.

Since 1979, a team of Soviet-Belgo-Dutch geologists have studied the Upper Famennian and Tournaisian strata in the eastern Omolon area (NE-USSR, fig. 1). This area received special attention for a possible new definition of the Devonian-Carboniferous boundary. Initially, attention was mainly paid to the bio- and lithostratigraphy. Later the sediment petrography and a paleogeographic model was worked out more in detail (Simakov *et al.*, 1983; Swennen *et al.*, 1986). These investigations were supplemented by a lithogeochemical survey. In this paper results of that survey will be discussed. Basic data on the lithogeochemistry of the different sections are summarized in Swennen *et al.* (1985).

2. - GEOLOGICAL SETTING

The Upper Famennian and Tournaisian strata in the eastern Omolon area were studied in four localities, namely Pushok, Perevalny/Sikambr, Elergetkhyn and

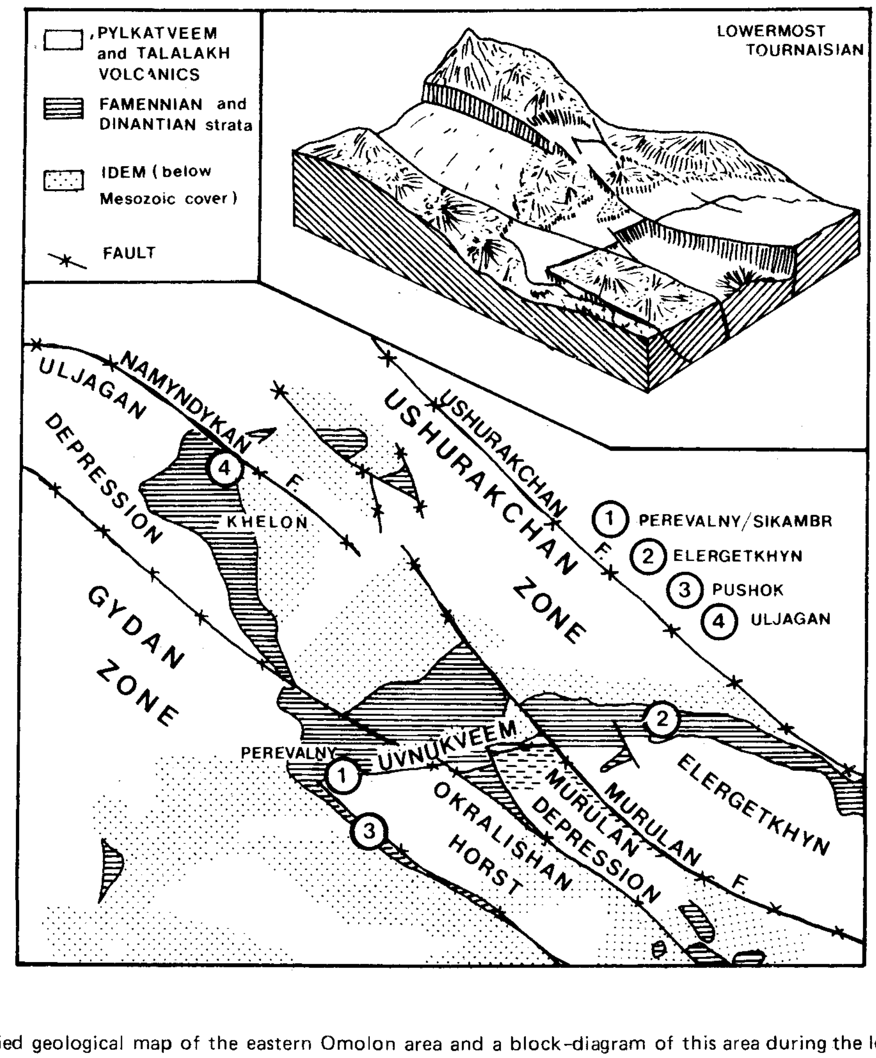

Figure 1. - Simplified geological map of the eastern Omolon area and a block-diagram of this area during the lowermost Tournaisian.

Uljagan (fig. 1). The strata mainly consist of carbonates with subordinate (silicified) shales. Locally volcanomict conglomerates and (gravelitic) sandstones were found, especially at the base of the succession. The sedimentary facies varies from deep subtidal (shales and moravamminid-micrites) through shallow subtidal (biosparites, intrasparites and oosparites) into intertidal to supratidal (sabkha-type sediments). A detailed sediment-petrographic description can be found in Swennen *et al.* (1986). Several of the inferred transgression-regression (T/R) cycles can be correlated with similar events elsewhere (USA, Europe, . . .) suggesting that these represent repeated eustatic sea level fluctuations. However lateral and vertical facies variations especially during the late Strunian to the Lower Tournaisian suggest that some of these major sea level fluctuations are masked by differential warp of the block-faulted basement (Swennen *et al.,* 1986). Especially near the Devonian-Carboniferous boundary tectonic activity along the E-W trending Uvnukveem fault (fig. 1) was inferred from the facies variations in the different localities.

3. - ANALYTICAL PROCEDURE

182 representative samples were collected by chip sampling. A special effort was made to sample carbonate lithologies. After crushing and milling to a size lower than 100 μm, two grams of the fine material were decomposed in 20 ml 12,5 N hydrochloric acid. After complete reaction the dissolved sample was evaporated; the residue then was dissolved in 40 ml 2,5 N hydrochloric acid. After filtration the fluid was deluted to 100 ml. Mg, Sr, Na, Zn, Pb, Fe, Mn and K were analysed by atomic absorption spectrometry. Matrix interferences for Sr, Pb and K were avoided by comparing the samples with representative calcite and/or dolomite calibration curves (Van Orsmael, 1982). Background-absorption interferences within residue-rich samples were corrected using the hydrogen lamp continuum (Govett & Whitehead, 1973). The insoluble residue content (IR) was determined gravimetrically. Analytical precision was generally better than 10 percent at the 95 °/o confidence level. The Mg and IR concentrations are given in percent while the other element concentrations are given in ppm.

4. - DESCRIPTION OF THE LITHOGEOCHEMICAL DISTRIBUTION PATTERNS

The lithogeochemical distribution patterns in the composite sections of Perevalny/Sikambr, Elergetkhyn, Pushok and Uljagan are presented respectively in figures 2, 3 and 4. Special attention will be paid to anomalous intervals, i.e. intervals with concentrations more than two standard deviations above the mean.

4.1. - PEREVALNY/SIKAMBR LOCALITY

The Perevalny as well as the Lower Elergetkhyn limestones are rather impure as can be deduced from the high IR and K values (fig. 2). A rather uniform pattern of the IR/K ratio ($\bar{X}$ IR/K = 0.73; σ IR/K = 0.28; n = 24) is present indicating that K is derived from clays. Fe displays a covariant behaviour with IR and K.

The value of the other elements are rather low, with the exception of Pb and Mn. Pb displays an irregular pattern with highest values (up to 770 ppm) near E-W trending faults. High Mn values occur within the interval anomalous in Pb. The fact that a clear covariance between Mn and Pb, or between Mn and Fe, IR and K, is absent suggests that the Mn distribution is not controlled by phases linked to a Pb phase or with the insoluble residue. It is likely that similar anomalous Pb and Mn values will occur in the surrounding coarse-grained sandstones since in these strata galena traces and pyrolusite dendrites were observed macroscopically. However, these sandstones were not analyzed.

The Middle and Upper Elergetkhyn (deep subtidal) limestones display, with the exception of Zn and Mn, rather normal contents for most of the measured elements. An increase in Sr and Fe contents towards younger strata, however, is apparent. Anomalous Zn and Mn values were found near the Devonian-Carboniferous boundary in two sections. The Mn anomaly in the limestones is obscured since the surrounding strata are dolomitized or rich in IR. The high Mn content within the latter strata can be explained by adsorption of Mn on hydrous Fe and IR phases, as can be inferred from the covariance of Mn with Fe, IR and K. The Zn, Mn anomaly, which develops within limestones as well as within dolostones, has a vertical extension of about 70 m. The dolostones which occur within this interval are Fe and Mn-rich (Fe ≅ 1,0 °/o and Mn ≅ 0,4-0,3 °/o); Na also is enriched while IR and Sr occur in low concentrations. Since similar Fe, Mn-rich dolostones displaying anomalous Zn values occur about 100 m below (Lower Elergetkhyn Formation) and about 70 m above (Uppermost Elergetkhyn Formation) the major Zn-Mn anomaly (fig. 2), a genetical link between these different dolostone levels seems likely. These dolostone strata give rise to a covariant pattern between Mg, Na, Fe, Mn, -Sr and -IR (fig. 2).

The Mol limestones display an irregular distribution pattern for most of the elements. A general decrease in Fe, IR and Na contents from the rather deep-marine biomicrites towards the overlying shallow subtidal strata is observed.

The majority of the shallow-marine Sikambr limestones is partly dolomitized. The sample which was taken within the early-diagenetic dolostone layers with anhydrite relics (fig. 2; *) is characterized by moderate values for most elements. However, when comparing its geochemistry with that of the underlying dolostones the Sr (199 ppm) and K (783 ppm) values are high. The increase in IR content towards

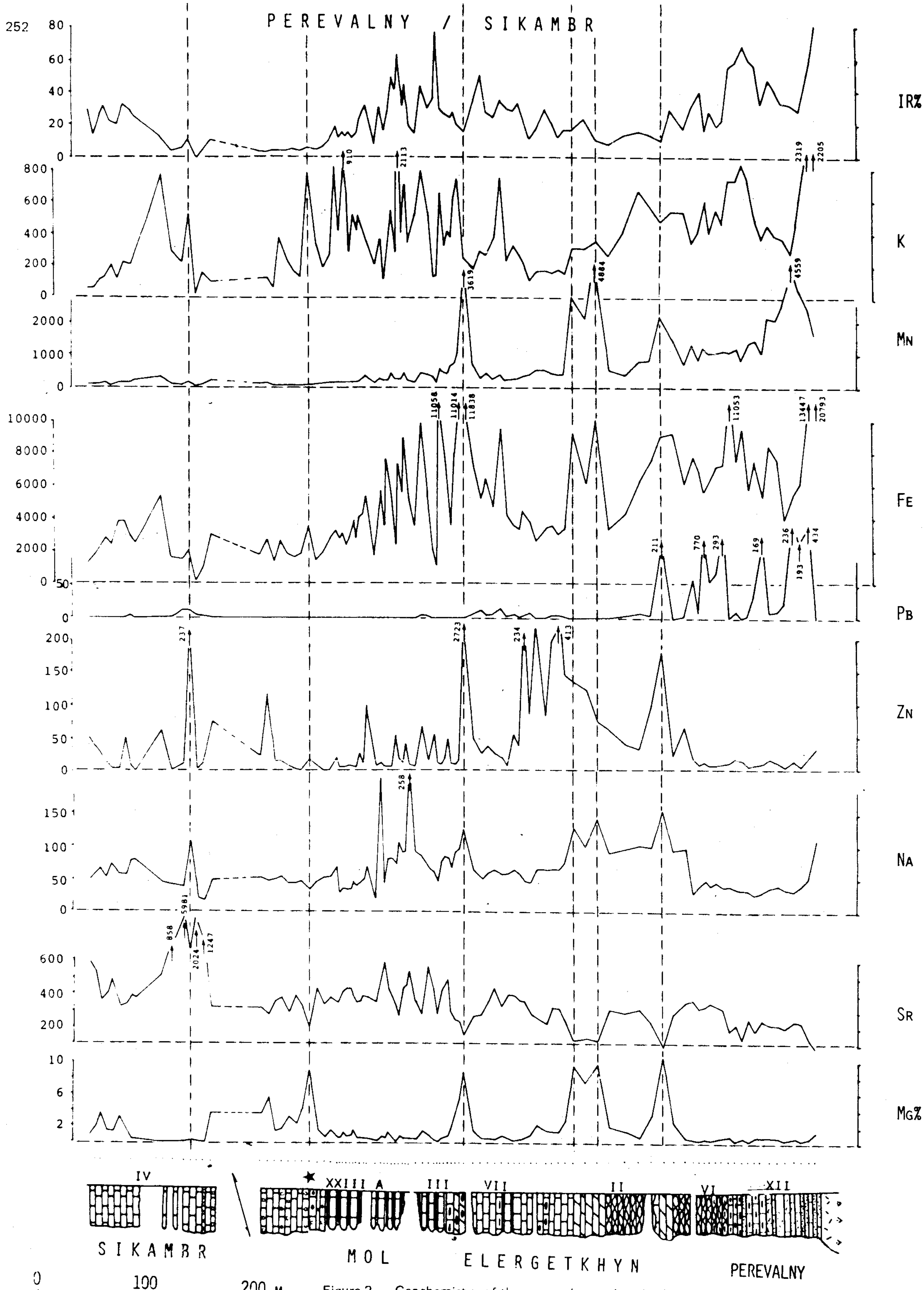

Figure 2. - Geochemistry of the composite sections in the Perevalny/Sikambr location. (* : position of the analysed early diagenetic dolostone layer).

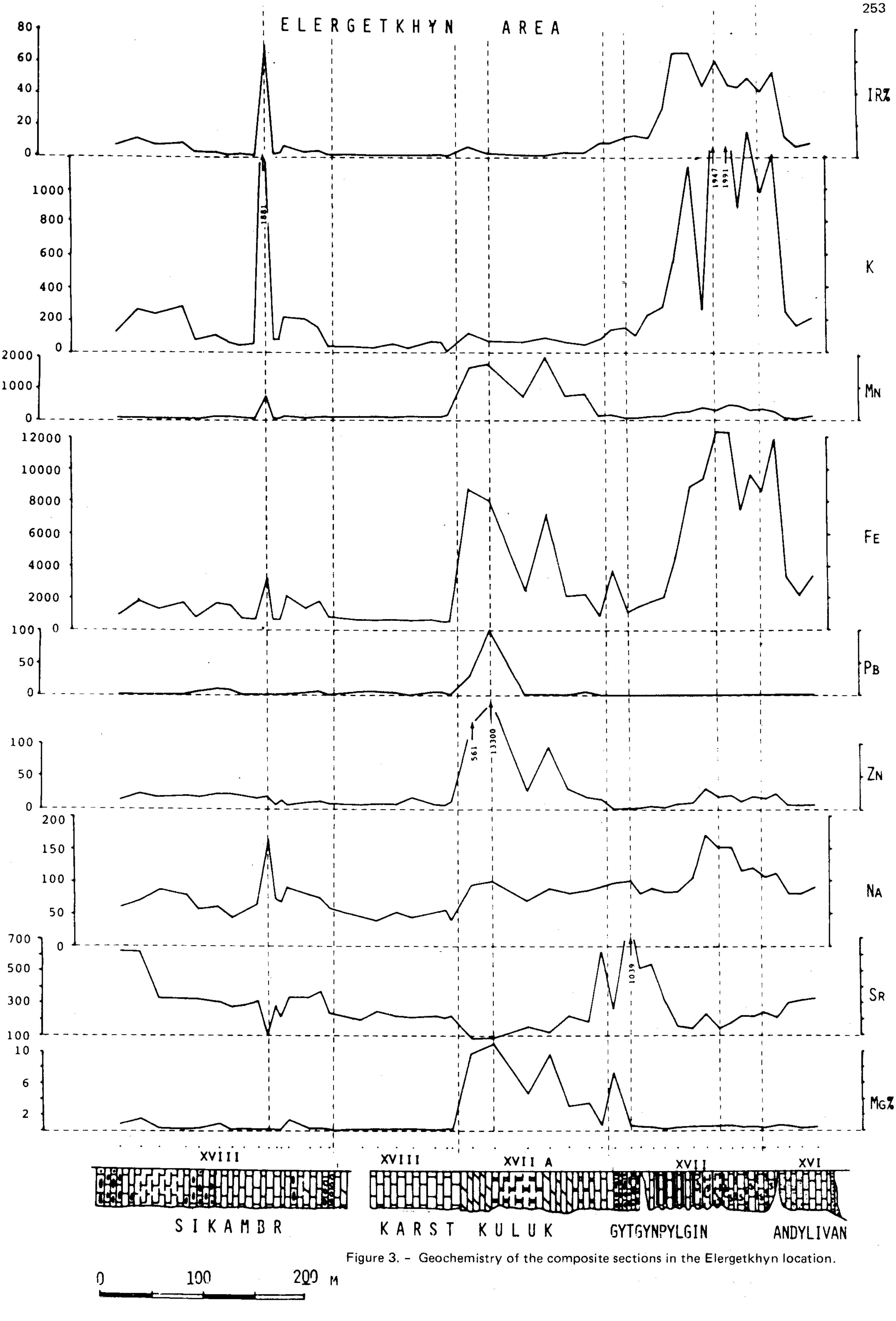

Figure 3. - Geochemistry of the composite sections in the Elergetkhyn location.

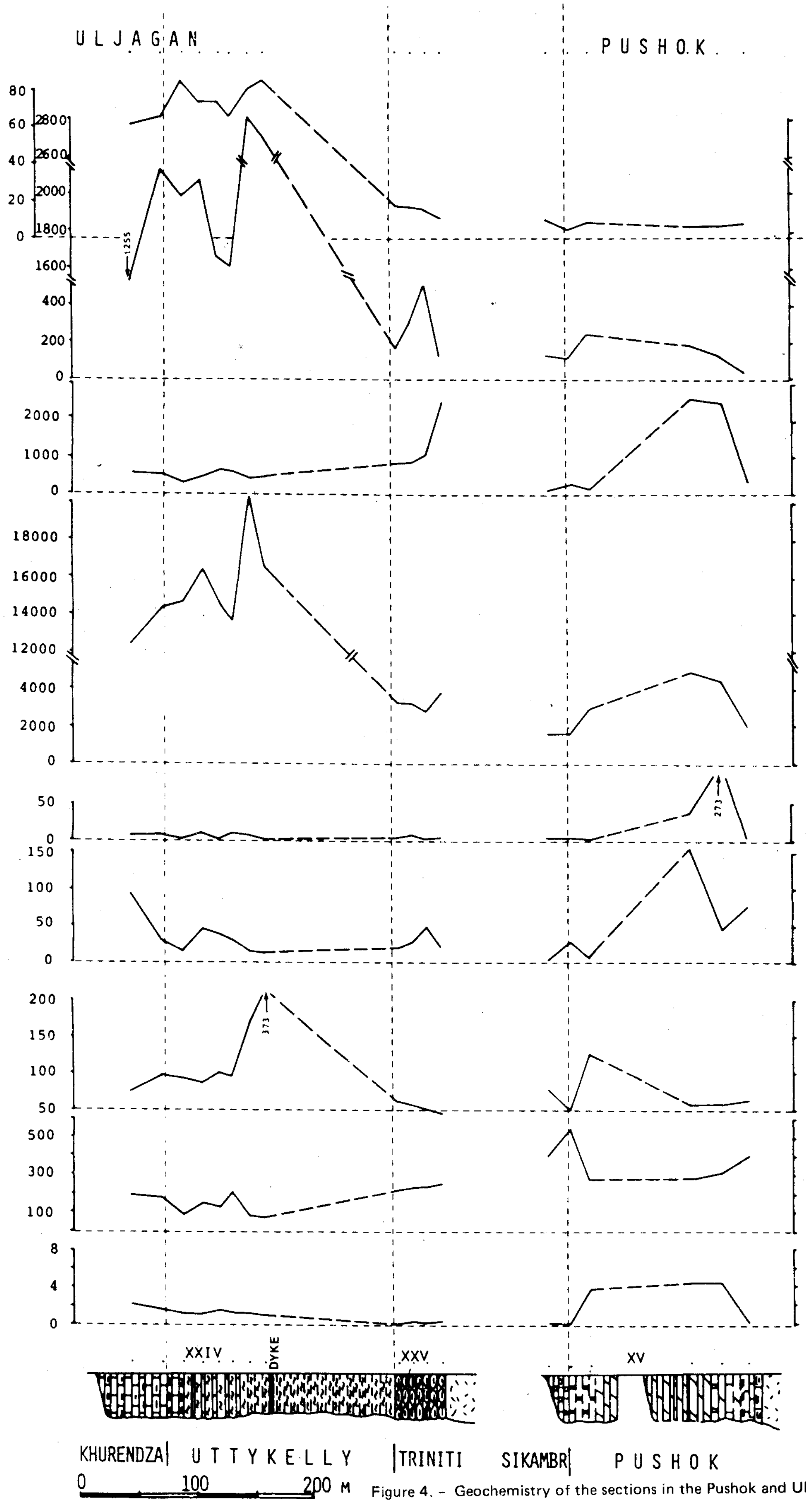

Figure 4. – Geochemistry of the sections in the Pushok and Uljagan locations.

younger strata is related to the increase in the degree of silicification/chertification. Furthermore a covariant pattern between K and Fe is present.

A remarkable feature within these Sikambr strata is the Sr anomaly within sabkha-like strata such as the zebra limestones (up to 5981 ppm), palisade calcite crystals (up to 2024 ppm) and algal micrites (up to 665 ppm). With the exception of the algal micrites, these strata are characterized by low Na, Fe and Mn contents. Rather high Zn contents (up to 237 ppm) were found in the algal micrites.

4.2.- ELERGETKHYN LOCALITY

The limestone strata of the Lower and Middle Andylivan Formation display normal values for all measured elements (fig. 3). However, the Upper Andylivan and Lower and Middle Gytgynpylgin strata which mainly consist of intensively silicified biomicrites are characterized by very high IR, K, Fe and Na values. Also slightly higher Zn and Mn values occur over this interval. A covariant pattern between Fe and K is recognizable. In the overlying Upper Gytgynpylgin strata a decrease in concentration of all these elements can be observed. However, here a Sr anomaly is present.

In the Kuluk Formation an increase in the degree of dolomitization can be inferred from the Mg pattern. From the lithogeochemical profile (fig. 3) a covariance between Mg, Fe, Mn and Zn can be seen. At the top of the Kuluk Formation, notably around the Devonian-Carboniferous boundary, an interval of about 80 m with abnormal values for Zn (up to 1.3 °/o) and Pb (101 ppm) is present. In this interval silicified anhydrite nodules are present as well as an important breccia level.

The Karst and Sikambr limestones display normal distribution patterns with somewhat higher values in the youngest strata; the rather high Sr values in the top-strata occur near dyke intrusions. The single horizon with high values of IR, K, Fe, Mn and Na corresponds to intensively silicified biomicrites.

4.3. - PUSHOK LOCALITY

The six representative samples from this location show high Zn, Pb, Fe and Mn values above the base of the partly dolomitized Pushok limestones (fig. 4). These high metal contents occur above the Devonian-Carboniferous boundary. The Upper Pushok and Sikambr limestones, which reflect subtidal sedimentation conditions, are characterized by normal contents for all elements; only near the top of the Pushok Formation a high Sr interval is present.

4.4. - ULJAGAN LOCALITY

From the lithogeochemical profile (fig. 4) it is clear that, in contrast to the intensively silicified deep marine Uttykelly and Khurendza strata, the Triniti limestones are characterized by low IR, K, Fe and Na values. Only Mn and Sr occur in higher contents. Within the silicified strata a covariant pattern between Fe and K is present; these elements occur in very high concentrations. For the other elements more normal contents are recorded, except for Na showing high values next to a diorite dyke.

5. - DISCUSSION AND INTERPRETATION OF THE GEOCHEMICAL PATTERNS

A major feature in nearly all locations is the strong covariance between K, IR and Fe associated with high contents in clay-enriched carbonates. Since the limestones are poor in feldspar K is mainly provided by clays. The covariance indicates that Fe is related to the presence mainly of clay phases. However, part of the Fe is also related to goethite rims occurring around pyrite. Since pyrite phases mainly occur in association with clays and silicified intervals, an Fe-IR correlation once again will appear. Within such clay-enriched sequences higher amounts of Mn and Zn also were recorded; these can be explained by similar adsorption phenomena on clays and by the co-precipitation and adsorption on goethite phases. The higher Na contents in these intervals is related to the clay content.

On the contrary, it often occurs that Sr and Mg are negatively correlated to IR. This shows that Sr and Mg are carbonate-controlled; consequently an increase in IR content will lower the Sr and Mg content. To compare the Sr contents of the different limestone strata an IR correction is necessary. Plotting of the corrected Sr data into a histogram results in a bimodal pattern (fig. 5). This bimodality is facies-controlled since the lowest Sr population is composed of shallow marine limestones, while the high Sr population consits of rather deep subtidal strata. Their respective mean values are 290 ppm (σ = 59 ppm, n = 24) and 396 ppm (σ = 45 ppm, n = 13).

By studying the Mesozoic strata of the central Western Carpathians Veizer & Demovič (1974) observed a similar pattern. They interpreted the high Sr content within deep sea limestones to be related to the higher proportion of stable low Mg-calcite in the original sediment, while shallow-marine limestones mainly consist of high Mg-calcite. According to these authors the initial Sr concentrations of about 1000 ppm within low Mg-calcite is lowered to a much smaller degree than within the unstable high Mg-calcite during diagenesis.

Most of the dolostones, occurring around the Devonian-Carboniferous boundary, are Fe, Mn, Zn, Na, (Pb) rich, whereas low contents for K, IR and Sr are present. This indicates dolomitization by Fe, Mn-rich solutions preferentially occurring in pure

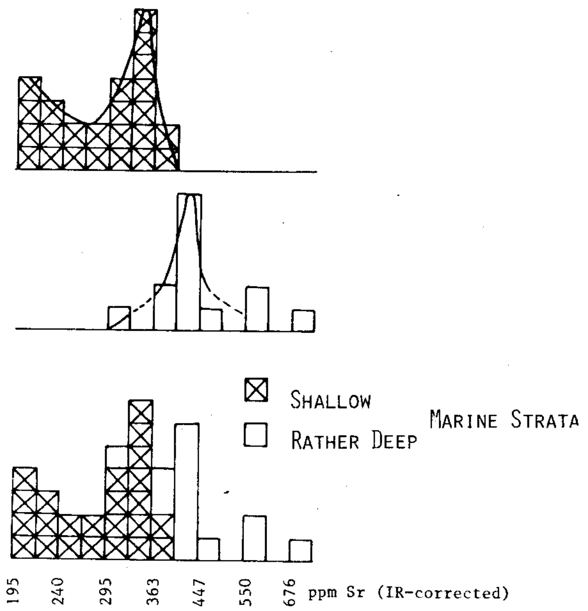

Figure 5.
Histogram of the IR-corrected Sr-distribution in the limestones (< 2 °/o Mg) in the Elergetkhyn location.

limestones. A lixiviation of Sr during the dolomitization explains the low Sr content in these dolostones, while Na was introduced. Part of the lithogeochemical features within these dolostones, particularly the high Fe and Mn contents may also be related to dedolomitized intervals; a few intervals were petrographically studied. These are characterized by goethite rims occurring around the dedolomitized crystals. Due to adsorption on the hydrous Fe phases, these strata often yield high metal concentrations (Swennen *et al.*, 1983). However, it is unlikely that the high Zn and Pb contents can be explained in this way since abnormal Zn values were also recorded in the surrounding limestones (Perevalny location) and since such phenomena cannot produce anomalies up to 1.3 °/o (Elergetkhyn location). The dolostone level in the Sikambr Formation (Perevalny location) is characterized by moderate values for most elements, except for Sr and K. According to Weber (1964) these values are compatible with their early diagenetic origin.

In conclusion we may state that the lithogeochemical patterns are to a large extent controlled by non-carbonate phases. Similar observations have been made in the Belgian Dinantian carbonates (Van Orsmael, 1982; Swennen, 1985) and in the Liassic carbonates of France (Barbier, 1979). Furthermore diagenetic processes such as dolomitization, dedolomitization, recrystallization, etc, also influences the lithogeochemical patterns. By controlling these parameters (IR-correction, dolomitization correction, . . .) it is possible to obtain paleoenvironmental information from the lithogeochemical data. Apart from the patterns explained by non-carbonate phases and diagenesis, four lithogeochemical anomalies are present (fig. 6) :

1. A regional Zn (Pb, Mn) anomaly (Devonian-Carboniferous boundary);
2. A Sr (Zn) anomaly (Sikambr Formation; Perevalny/Sikambr location);
3. A Sr anomaly (Upper Gytgynpylgin Formation; Elergetkhyn location);
4. A local Pb, Mn anomaly (Perevalny and Lower Elergetkhyn Formation; Perevalny location).

Some of these anomalies also match anomalous Fe and Mn values. But as previously discussed it is often difficult to recognize these intervals because of the interference of IR-phases and dolomitization.

5.1. - REGIONAL ZN (PB, MN) ANOMALY (DEVONIAN-CARBONIFEROUS BOUNDARY)

A Zn (Pb, Mn) anomaly is present near the Devonian-Carboniferous boundary. It is found in different sections in the three localities Pushok, Perevalny/Sikambr and Elergetkhyn, which occur in the southern part of the Omolon area. Its lateral extension is at least 45 km; its vertical extension is also important (> 50 m). This anomaly has a regional significance.

The anomaly is well expressed for Zn and sometimes for Pb. Higher contents of Mn also occur. However, overlap by Mn adsorbed on IR-phases and redistributed by dolomitization obscure the pattern. It is not known if this anomaly occurs also in the northern part of the Omolon basin (Uljagan location) since this stratigraphical interval could not be studied because of a gap in the outcrop.

The anomaly coincides with important facies variations which have been explained by differential downwarp of the block-faulted basement (Swennen *et al.*, 1986). Fault activity especially was recorded during the considered time-interval along the Uvnukveem fault (fig. 1). This tectonic activity in Perevalny valley is characterized by a drastic change in the sedimentary environment, since a thin dolostone level with anhydrite pseudomorphs is intercalated in rather deep subtidal moravamminid-micrites. This sequence is followed by an important shallowing of the sedimentation environment. At Pushok the sedimentation only started during this period. At Elergetkhyn the anomaly coincides with an important regression.

Since major tectonic activities occurred over the anomalous stratigraphical interval in the southern Omolon area, the anomaly can be explained by mineralizing fluids from active faults. This mechanism, described as seismic pumping (Sibson *et al.*, 1975) was invoked by Large (1983) to explain the formation of sediment-hosted submarine exhalative Pb-Zn deposits. Several of the features of this type of ore deposits discussed by Large (1980) were also recognized in the southern Omolon area. They are :

1. The presence of different order-types of basins. Shilo *et al* (1984) recognized several first-order basins (size several 100 km : the Korkodon Land, the Gizhiga archipelago and the Omolon archipelago), the existence of second-order basins (size several 10 km : e.g. Uljagan depression) and third-order basins (size 100 m to several km : e.g. Pushok basin). Sedimentation during the Devonian-Carboniferous transition period in the different subbasins occurred in low-energy sedimentation conditions. These are essential for the preservation of para-stratabound anomalies and ore deposits.
2. Active tectonism influenced the sedimentation especially from late Strunian to Lower Tournaisian. During such periods subsidence was mainly controlled by faulting. Different lineaments (the N-S trending Namyndykan and Murulan faults) and the E-W trending Uvnukveem fault system were activated (fig. 1). Tectonic activity along this last fault system is of interest since this Zn (Mn, Pb) anomaly was found in the three localities (Pushok, Perevalny/ Sikambr and Elergetkhyn) which occur next to this fault (fig. 1). The presence of a breccia horizon in the Elergetkhyn location where the highest Zn values were recorded could provide a further argument for tectonic instability. A detailed study of this breccia might yield arguments for such a relation. This is of special interest since Taylor (1984) recently drew the attention to the occurrence of shake breccias from the vicinity of the Silvermines orebody (Ireland).
3. Exhalative activity and volcanism can be deduced from the following observations :
   - bentonite and tuffitic intercalations occur in the abnormal succession respectively at Perevalny and Elergetkhyn. During this period igneous activity is also reported from the Korkodon Land. Bentonite and tuffitic horizons have been reported from nearly all sediment-hosted exhalative ore deposits. Penecontemporaneous igneous activity is important because it indicates the development of an anomalously high geothermal gradient. This is considered as a requirement for convective circulation systems (Large, 1980 and Russel *et al.*, 1981).
   - in the anomalous levels traces of sphalerite and galena were found. They occur in close association with framboidal pyrite spots. Furthermore quartz pseudomorphs after barite were found. This last feature is common for sediment-hosted Pb-Zn mineralizations. Similar observations have been made in the Navan area (Ireland; unpublished research).
   - major silicification and chertification occurred in the strata hosting the geochemical anomaly. At Pushok the biostromal buildups and the evaporite relics are nearly completely silicified. At Perevalny/Sikambr chert nodules become an important component, while the breccia at Elergetkhyn is nearly entirely composed of chert and silicified evaporite fragments. Silicification and chertification phenomena have been reported to be a prominent feature near sediment-hosted massive sulphide deposits; e.g. Mc Arthur River deposit : Australia (Oehler & Logan, 1977); Tynagh : Ireland (Clifford, personal communication, 1985).
   - dolomitization is present in and around the anomalous zone. At Elergetkhyn the whole sequence is nearly completely dolomitized. At Perevalny/ Sikambr only pure limestone strata in the lower part of the anomaly are altered. At Pushok the strata are partly dolomitized. A remarkable feature everywhere is that these dolostones are enriched in Fe and Mn (Fe $\cong$ 0,8 - 1,0 °/o and Mn $\cong$ 0,4 - 0,2 °/o). Zn and Na occur also in higher concentrations (Zn $<$ 50 ppm and Na = 130 ppm). Similar Fe and Mn enriched dolostones were described around different sediment-hosted ore deposits; e.g. Tynagh (Schulz, 1966); Mc Arthur River deposit (Lambert & Scott, 1973)). The last authors suggested that the dolomitizing solutions ascended along the same channelways as the ore-bearing solutions. The period over which the Fe-Mn-bearing dolomitizing solutions were available apparently corresponds with the main period of formation of tuffaceous sediments, a feature which can also be observed in the Omolon area. The Fe-Mn-rich dolostones around the Mc Arthur River deposit were distributed over a roughly semi-circular area, approximately 15-20 km in diameter. This size is also possible in the Omolon area.
   - below and above the major Devonian-Carboniferous anomaly, smaller Zn (Pb) anomalies occur in the Perevalny location (fig. 6 : 1A and 1C). These minor anomalies are also characterized by silicification and chertification as well as by Fe-Mn dolostones. Furthermore important facies changes were observed at least for the uppermost anomaly (1C). This indicates that metalliferous exhalative solutions were intermittently available during a considerable time before and after the formation of the major anomaly. The limited vertical and lateral extension of these anomalies, however, indicates that the related exhalations were less important. Similar geochemical features, pointing to periodical exhalations were observed near the Mc Arthur River deposit (Lambert & Scott, 1973).
   - the difficulty to apply detailed biostratigraphic tools near this Devonian-Carboniferous boundary might indicate that the sedimentary environment eventually became toxic; consequently life became endemic (Simakov *et al.*, 1983).

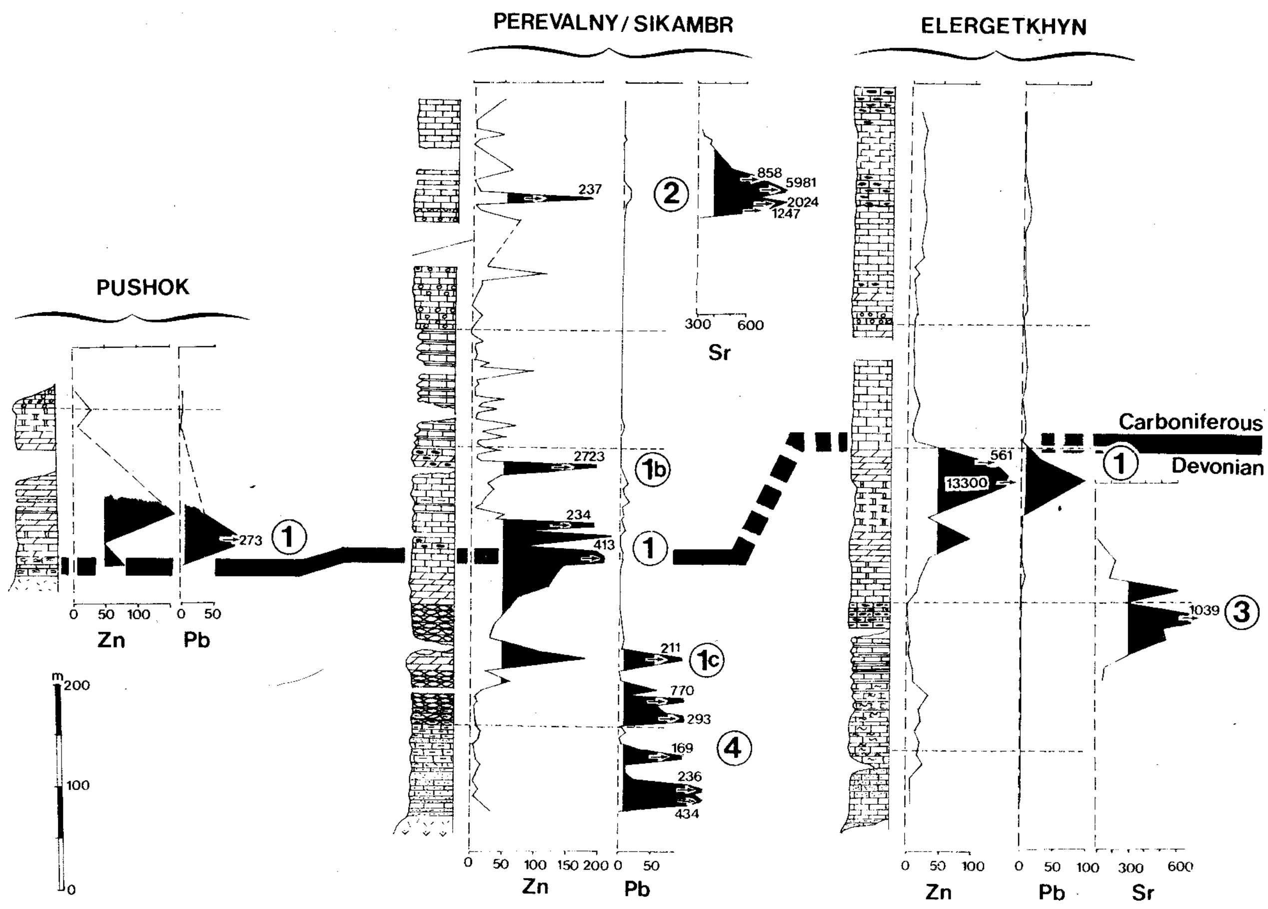

Figure 6. - Position of the different anomalies in the eastern Omolon area.

These arguments suggest that this para-stratabound anomaly might be exhalative in origin. Its important lateral and vertical extension, as well as the intensive dolomitization and chertification/silicification phenomena points to the possibility of an important mineralization around this stratigraphic level. Further prospection should be focussed on the NE-SW trending fault system. The fact that different minor anomalies occur below and above the major "Devonian-Carboniferous" anomaly at Perevalny, suggests that exhalation was most prominent in this area. The greater thickness (~ 100 m) of the anomalous strata is in agreement with this interpretation, although, abnormal values are lower than for example at Elergetkhyn. In the last area sedimentation occurred in a semi-restricted environment while subtidal open-marine conditions occurred at Perevalny. A dilution effect might explain this discrepancy, although, redistribution related to dolomitization at Elergetkhyn can also have an effect. Taking into account that the mineralizing solutions were heavy, being salt-laden, and that they drifted downslope, the major concentration of elements will occupy the deepest parts of the depression. A more detailed sediment-petrographic study combined with lithogeochemistry involving material from other sections would possibly help to pin-point this fault-controlled brine-filled third-order basins.

Similar para-stratabound Devonian-Carboniferous anomalies have been recorded from elsewhere. Important enrichments of Pb, Zn, Ag, Ba, Mn and Fe were reported by Lur'ye (1953) over a large area in central Kazakhstan (USSR). This author interpreted them as a primary accumulation; a relation with the Pb-Zn Mirgalimsar ore deposit, situated 15 km south of the sampling area was suggested. Kasig *et al* (1984) also found anomalous Zn, Mn and Ba values *near* this stratigraphic level in the Sauerland area (Germany). These abnormal values were explained by hydrothermal influences; unfortunately the lateral extension of this anomaly was not studied. Anomalous Zn, Mn and Fe values were also recorded near the Devonian-Carboniferous boundary in the Vesdre basin (Belgium); its origin and lateral extension however, are still under investigation (Swennen, 1984).

According to these features it seems worthwhile to continue the study of this stratigraphic interval. If this anomaly can be explained by a world-wide event is questionable. It seems more likely that different preconditions such as tectonic activity, a high geothermal

Table 1. - Geochemistry of some lithologies of the Sikambr Formation.

RESTRICTED SEDIMENTATION ENVIRONMENT	lithology	interpretation		Sr ppm	Zn ppm	Fe ppm	K ppm	IR %
	limestone breccia	evaporitic solution breccia		1247	10	973	163	4
	algal micrite with anhydrite relics	inter- to supratidal (sabkha)	A	665	237	2057	512	11
			B	502	60	5312	775	13
	zebra limestone	DCR-recrystallization product of algal micrites	A	5981	11	1503	224	6
			B	858	4	1664	279	4
	palisade calcite	selenite pseudomorphs		2024	1	244	34	0
	background values of the underlying strata (n = 13)		$\bar{x}$	338	24	2345	285	7
			σ	59	33	726	245	4

gradient, circulating fluids, etc. are needed for making a sedimentary basin of potential importance for mineralization.

5.2. - SR (ZN) ANOMALY (SIKAMBR FM.; PEREVALNY/SIKAMBR LOCATION)

An important Sr anomaly, up to 35 m thick, was discovered in the Middle Sikambr Formation at Perevalny/Sikambr (fig. 6). Anomalous Sr values occur in limestone breccias, algal micrites with anhydrite pseudomorphs, zebra limestones and palisade calcite layers. In table 1 the sedimentological interpretation and the Sr, Zn, Fe, K and IR contents of these strata are given. The breccia, mainly composed of algal micrite, displays abnormal Sr values, while the contents of other elements are low. The algal micrites are also characterized by abnormal Sr contents and by high to anomalous Zn and Pb values. It is not known if Zn and Pb are adsorbed on organic phases or if they occur as dessiminated sulphide phases. Ferguson & Bubela (1974) demonstrated that metals can be adsorbed onto the particulate organic matter of algae.. However, other studies have not necessarily yielded the same results (Dissanayake, 1985). The occurrence of dessiminate Zn, Pb sulphide phases within algal mats was reported from different places. In order to explain the association between algal mats and stratiform metalliferous deposits Renfro (1974) developed his "Sabkha-Process" model. He proposed that algal-mat facies upon burial in a sabkha environment will become saturated with hydrogen sulphide generated by anaerobic bacteria. As terrestrial-formation water passes through the hydrogen/sulphide-charged algal mats, its load of dissolved metals is reduced and precipitates interstitially as sulphides. Eugster (1985) however, pointed out that none of these syngenetic concentrations are usually high enough to form an ore deposit. Nevertheless, a geochemical coherence between base metal enriched algal mats and ore deposits may exist.

In that case further enrichment through remobilization, transport and deposition processes is necessary. The high to anomalous Zn and Pb contents in the Sikambr algal mats are interpreted as a possible proto-ore. Since the zebra limestones, which are the recrystallization products of the algal micrites, possess low Zn, Pb, Mn and Fe contents remobilization of base metals within this sequence occurred. These metal-enriched fluids may have played a role in ore formation elsewhere.

Another characteristic feature of the zebra limestones is their low K, IR and partly Na contents in comparison to the algal mats indicating that during diagenetic crystallization the detrital components of the micrites such as clays were altered. Zebra limestones, however, possess very high Sr contents. The important variations in Sr content can be explained by the fact that the remobilized Sr precipitated as individual celestite crystals.

The palisade calcite crystals, which were interpreted as selenite pseudomorphs, also possess anomalous Sr contents, while all other elements occur in extremely low concentrations. As in the zebra limestones Sr is incorporated within small celestite crystals; the low content of the other elements is explained by their initial low content and by the pseudomorphose process.

In conclusion we may state that the high Sr contents within the breccia and algal micrites is compatible with the deduced hypersaline sedimentation environment. As already discussed by several authors (Veizer & Demovič, 1974; Kranz, 1973; Swennen *et al.*, 1983) Sr can be used as a facies indicator. During diagenetic crystallization and/or pseudomorphoses Sr seems to be concentrated into celestite, while a loss of other elements is apparent.

5.3. - SR ANOMALY (UPPER GYTGYNPYLGIN FM; ELERGETKHYN LOCATION)

Over an interval of about 60 m, anomalous Sr values were found in chert-rich biomicrites with shale intercalations of the Upper Gytgynpylgin Formation. As previously discussed the background value of Sr (396 ppm; $\sigma = 45$ ppm; $n = 13$) within these rather deep-subtidal sediments is probably related to the higher proportion of the stable low-Mg calcite in the original sediments. An initially higher amount of this mineral phase within the considered abnormal interval cannot explain in an adequate way the anomalous Sr contents. A possible interpretation is the interference of intercalated shale units, inhibiting the loss of Sr during diagenesis. High to abnormal Sr contents within clay-rich Triassic strata were explained in a similar way by Veizer & Demovič (1974) and Kranz (1976). Swennen & Viaene (1981) proposed a similar interpretation for a Sr anomaly within Visean strata; however, there also abnormal concentrations of Zn, Pb, Fe and Mn occur. This anomaly could also be genetically related to the overlying dolostones. Dolomitization will normally lower the initial Sr content. However, little information is available on what occurs with the liberated Sr. In our case it seems possible that part of the Sr precipitated or became incorporated within calcite (calcite veinlets) or was adsorbed by clays near the dolomitization front. This interpretation could also explain the absence of abnormal contents of the other elements since they were not expulsed during dolomitization. Further research is needed to solve this problem.

5.4. - PB, MN ANOMALY (PEREVALNY - ELERGETKHYN FM; PEREVALNY LOCATION)

Within the Perevalny and Lower Elergetkhyn strata at Perevalny anomalous high Pb values, displaying an irregular pattern, were found in two sections around faults. In comparison with the overlying limestones, high Mn contents also occur over these strata. In contrast to Pb its lateral extension is much more developed. None of the other elements, with the exception of Fe perhaps, occurs in similar anomalous quantities. The high Fe contents can also be explained by adsorption phenomena on IR-phases, since a covariant pattern with K and IR is present. A covariance with these elements and Pb and Mn is not observed. These features and the fact that the anomaly was found in two sections both crosscutted by the same E-W trending fault-system, suggest an epigenetic origin. Therefore, its importance is local. As can be deduced from the geological map (Simakov *et al.*, 1979; fig. 10) this fault-system has a post-Lower Cretaceous age. Because of the very anomalous Pb values and the associated Mn halo, and the occurrence over an important distance (about 1,3 km), it seems possible that a fault-related Pb mineralization occurs in Perevalny valley. This possibility is also argued by the fact that in the Perevalny creek several pebbles and some cobbles of galena occur in the river bed. A soil geochemical survey around the E-W trending faults is proposed as a follow-up prospection tool.

6. - CONCLUSION

Different sections covering the Upper Famennian and Tournaisian in four localities, namely Pushok, Perevalny/Sikambr, Elergetkhyn and Uljagan, have been studied in the eastern Omolon area (NE-USSR). The lithogeochemical features within these strata can be summarized as follows :

1. The background lithogeochemical distribution patterns are mainly controlled by the insoluble residue phases.
2. The Sr distribution pattern within the limestones is facies-controlled . The background values within the rather deep-marine limestones are clearly higher than in the shallow-marine strata.
3. An important regional Zn (Pb, Mn) anomaly was found near the Devonian-Carboniferous boundary. Evidences of syndepositional fault activity during this period were found. This para-stratabound anomaly was interpreted to be exhalative in origin. Therefore the presence of sediment-hosted exhalative mineralizations in the area seems possible. However, this anomaly cannot be used for detailed correlation.
4. An important Sr (Zn) anomaly was recognized within the Upper Tournaisian hypersaline strata, confirming the use of Sr as facies indicator. Redistribution and remobilization processes due to diagenetic crystallization were discussed to explain the Sr patterns in the zebra limestones.
5. An important Sr anomaly was found at the dolomitization front at Elergetkhyn. A relation with the dolomitization process is possible, but this anomaly may also be caused by diagenetic "shielding effects" of the intercalated shale beds.
6. A local epigenetic fault-related Pb, Mn anomaly was discovered at Perevalny. It indicates a potential for mineralizations associated with the E-W trending fault system.

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