

EVALUATION OF TRANSGRESSION-REGRESSION EVENTS IN THE UPPER FAMENNIAN-TOURNAISIAN STRATA OF THE SOUTHEASTERN OMOLON AREA (NE-SIBERIA, USSR)

by

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(6 figures)

ABSTRACT. - The Upper Famennian-Tournaisian succession in the southeastern Omolon area (NE-Siberia, USSR) mainly consists of carbonates. Within this area sedimentary environments ranging from rather deep subtidal through intertidal to supratidal occur. The first are characterized by the deposition of moravaminid micrites, the latter by the occurrence of silicified anhydrite relics in sabkha-like sequences.

Several transgression-regression cycles in this area can be compared with major deepening and shallowing events elsewhere, suggesting that they are controlled by eustatic sea level fluctuations. However apparent sea level changes during the latest Strunian and early Tournaisian only have a local character; they therefore rather can be explained by differential downwarp of the basement in the considered area. Along these active faults it, periodically, came to the exhalation of (mineralizing) solutions.

RESUME. - La succession du Famennien supérieur au Tournaisien du sud-est de l'Omolon (Sibérie nord-orientale, URSS) consiste essentiellement en carbonates. A l'intérieur de cette aire sédimentaire apparaissent des environnements différents qui sont des milieux "subtidaux" assez profonds à des milieux "intertidaux" à "supratidaux". Les premiers sont caractérisés par le dépôt de micrites moravaminides, les derniers, par l'existence de restes d'anhydrite silicifiée dans des séquences de type "sabkha".

Dans cette région, plusieurs cycles de transgression-régression peuvent être comparés avec des changements de profondeur d'eau connus ailleurs, suggèrent qu'ils sont contrôlés par des fluctuations du niveau de la mer, à caractère eustatique. Cependant les variations apparentes du niveau de la mer intervenues pendant le Strunien tardif et le Tournaisien ancien n'ont qu'un caractère local. Pour cette raison, ils sont mieux expliqués par des mouvements différentiels du socle dans la région considérée. Des solutions minéralisées viennent périodiquement s'insérer le long de ces failles actives.

1. - INTRODUCTION

The Omolon area is situated in the northeastern part of Siberia (USSR; fig. 1a). Since 1979, the Upper Famennian and Dinantian (mainly Tournaisian) strata in this area have been studied by a team of Soviet-Belgo-Dutch geologists. This research resulted already in a number of reports, dealing with the general outlines of the geology and with the Upper Famennian to Tournaisian bio- and lithostratigraphy (Conil *et al.*, 1982, Simakov *et al.*, 1983 and Shilo *et al.*, 1984).

The present paper emphasises the influence of both eustatic sea level fluctuations and regional tectonism on the sedimentary history. The basic sedi-

mentpetrographic data of the different sections have been published in Swennen *et al.*, 1985.

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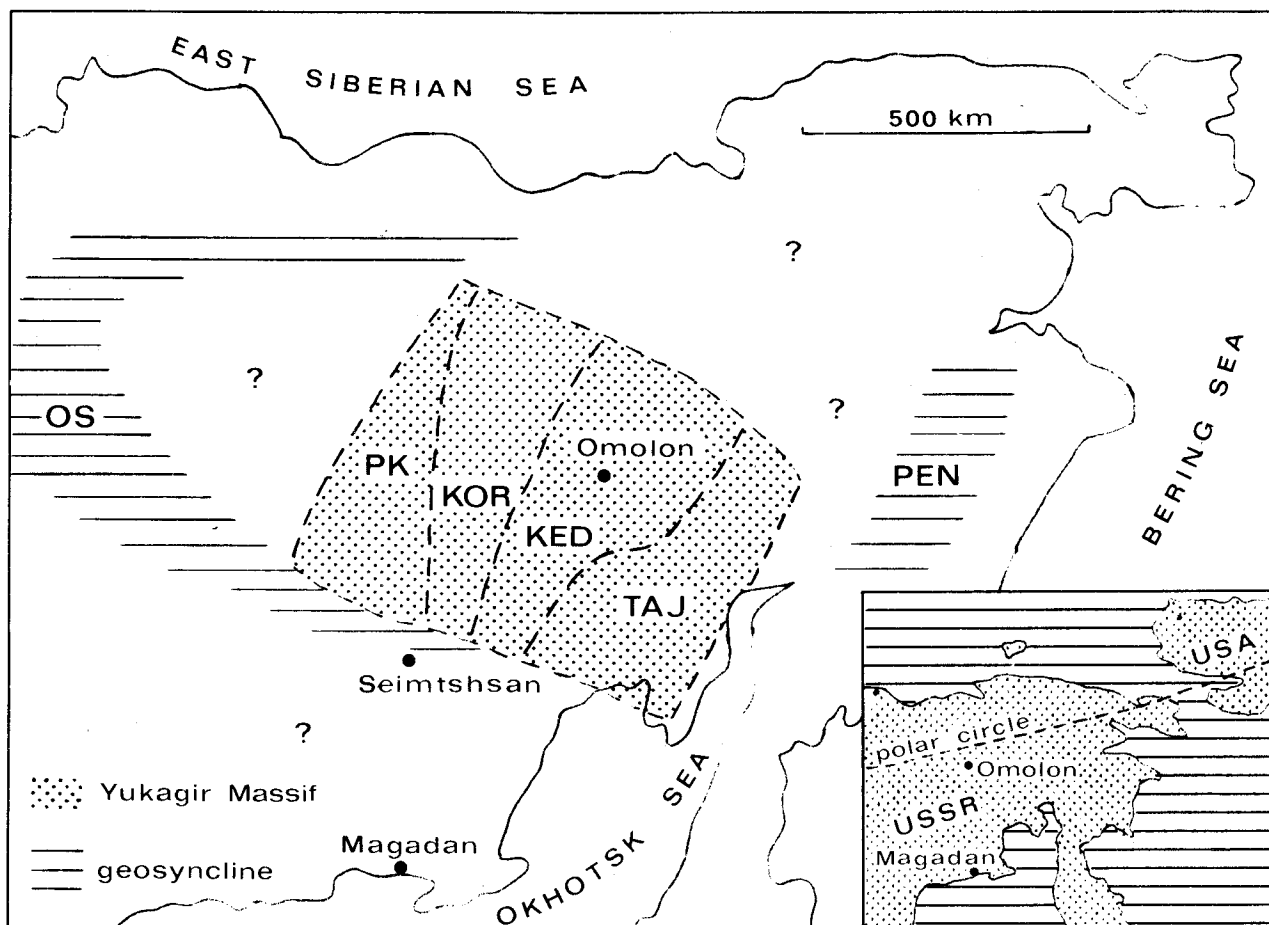


Figure 1. - Early Ordovician tectonic framework of NE-Siberia.

The Yukagir Massif (punctated) was bordered by the Omulevk - Selennyakh Geosyncline (OS) to the West and the Penzhin Geosyncline (PEN) to the East. The Yukagir Massif was subdivided in four composite blocks - Prekolyma (PK), Korkodon (KOR), Kedon (KED) and Tajganoss (TAJ) - which were separated by N-S striking fault zones.

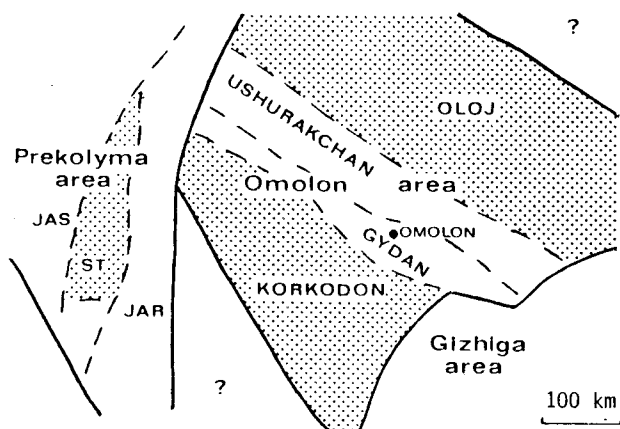
2. - GEOLOGICAL SETTING OF THE OMOLON REGION

The Omolon area formed part of the Yukagir Massif in Precambrian and Paleozoic times. The basement of this massif consists of metamorphic Archean rocks which are overlain by Riphean deposits of varying thickness (5-6 km in the West and 1-2 km in the central and eastern areas). Cambrian to Middle Ordovician volcanogenic, clastic and carbonate sediments occur in the central portions of the massif. The Yukagir Massif was subdivided in four composite blocks (Prekolyma, Korkodon, Kedon and Tajganoss; fig. 1b) which were separated by N-S striking fault zones. These are marked by important early to middle Ordovician granitoid intrusions. On both sides of the Yukagir Massif extended geosynclines developed during the Ordovician and Silurian, namely the Omulevk-Selennyakh to the West and the Penzhin to the East (fig. 1b).

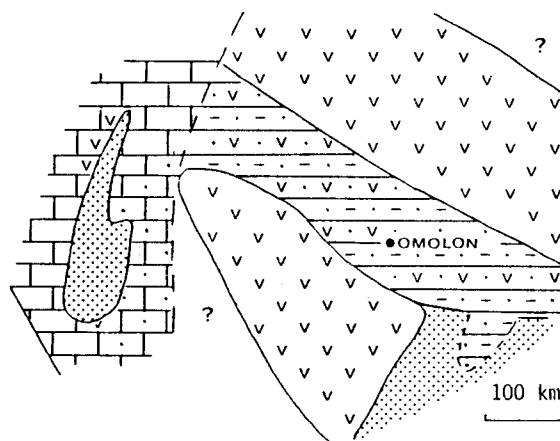
The Middle Paleozoic (Devono-Carboniferous) structural framework of the Yukagir Massif was produced by Caledonian movements. During the Silurian

to early Devonian, ancient fault zones reactivated in the Prekolyma and Gizhiga structural areas and resulted in new, NW-SE directed lineaments in the Omolon area (fig. 2a). These NW-SE striking lineaments in the Omolon area separate from South to North the Korkodon, Gydan, Ushurakchan and Oloj zones. The Korkodon and Oloj zones were predominantly positive areas during the Devonian and Dinantian, accumulating large amounts of red-coloured volcanites during the Middle Devonian and acting as sources for clastic material during the Upper Devonian and Dinantian. Some minor sedimentary intramontane basins developed within the Korkodon zone during the latter period.

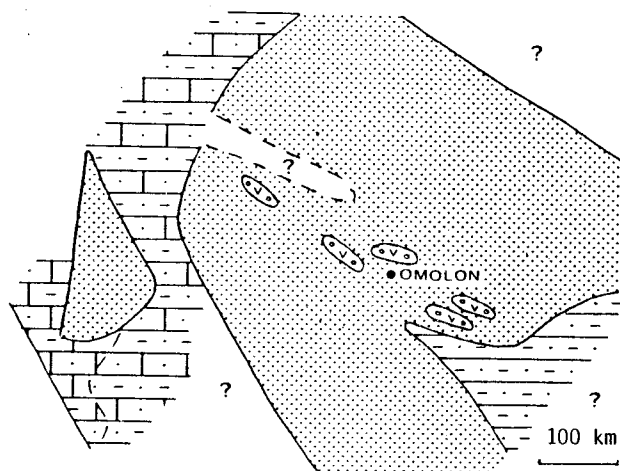
The studied portion of the Omolon area is situated in the southeastern half of the Gydan and Ushurakchan zones (to the East and South-East of the Omolon village). Deposition in this area occurred since the Lower Devonian (Ushurakchan zone) and notably since the Middle Devonian (Ushurakchan and Gydan zones). This area was repeatedly flooded by the sea since the early Devonian to the early Frasnian (fig. 2b) as can be de-



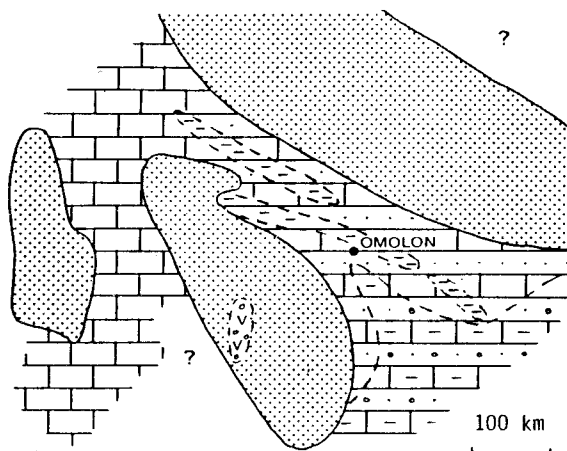
a: Devono-Dinantian structural framework



b: Lower to Middle Devonian paleogeography



c: Frasnian to Middle Famennian paleogeography



d: Late Famennian to Dinantian paleogeography

LEGEND



Figure 2. - Cartoons showing tectonic framework and paleogeography of Yukagir Massif during Devonian and Dinantian. 2a : Devono-Dinantian structural framework. Punctated : predominantly positive areas. Structural trends in Prekolyma and Gizhiga areas partly represent re-activated pre-Caledonian faults. Caledonian NW-SE striking lineaments in Omolon area obscure pre-Caledonian tectonic framework. Abbreviations : JAS : Jassachnaya Zone, ST : Stolbov High, JAR : Jarkhodon Zone. 2b : Lower to Middle Devonian paleogeography. 2c : Frasnian to Middle Famennian paleogeography. 2d : Late Famennian to Dinantian paleogeography. Legend : 1. positive area (sometimes flooded by the sea); 2. volcanogenic deposits; 3. conglomerates; 4. marine deposits; 5. carbonates; 6. clayey-silty deposits (sometimes silicified); 7. sandy deposits.

duced from the thick pile of marine clastics and carbonates alternating with volcanogenetic (partly red-coloured) deposits (fig. 3). A widely extended inversion affected the Omolon area during the Lower/Middle Frasnian to Middle Famennian. This period is marked by the development of several narrow intramontane grabens in the Gydan and Ushurakchan zones (fig. 2c), where basal, red-coloured polymict conglomerates

(including Archean to Middle Devonian rock pebbles) are overlain by red-coloured lavas and tuffs (fig. 3).

Renewed downwarp of the area, marked by marine transgressions in the Gydan-Ushurakchan zones, started during the early Upper Famennian (fig. 2d). Apart from red-coloured volcanomict conglomerates and (gravelitic) sandstones at the base, the Famennian and Dinantian deposits in these zones mainly consist of shelf carbonates with subordinate (silicified) shales. The latter abound in graben-like, fault-bounded depressions, such as the Uljagan Depression. During the late Devonian some E-W trending faults developed, which influenced the sedimentation in the southeastern Omolon area.

4. - LITHOLOGY, SEDIMENTPETROGRAPHY AND DEPOSITIONAL ENVIRONMENT

Within the southeastern Omolon area the Upper Famennian-Tournaisian strata have been studied in four areas : Pushok, Perevalny/Sikambr, Elergetkhyn and Uljagan (fig. 4). Their lithology, sedimentpetrography and depositional environment are reviewed here (fig. 5). Major correlation lines, which mainly are based on foraminifer and conodont assemblages are indicated. Note that the different lithologic units are described as "suites" in the Soviet literature. In the Omolon area these largely equal the term "formations". Therefore, these are referred to as formations in this paper.

4.1.- PUSHOK SECTIONS

These sections are situated in the southeastern part of Gydan Zone. The Pushok and (Lower) Sikambr Formation are exposed. These strata have been deposited during the latest Strunian to Middle Tournaisian (fig. 5).

4.1.1.- Pushok Formation

The base of the succession consists of biomicrites with birdseyes. They are overlain by two intensively silicified biostromal limestones, each of them capped by desiccation cracks and limestones with a huge amount of silica nodules. Since these cauliflower shaped nodules often display a chickenwire structure they are interpreted as pseudomorphs after anhydrite nodules. This interpretation is also supported by the fact that these nodules are built up (from fringe to core) by length slow chalcedony (mainly quartzine) and mega-quartz crystals with anhydrite relics (compare Swennen & Viaene, 1985). Similar silicified anhydrite nodules have been observed elsewhere in the Upper Famennian-Tournaisian succession of the southeastern Omolon area.

Upwards a rhythmic alternation occurs of coral-enriched dolostones, partly dolomitized algal mats and xenotopic (Fe-rich) dolostones with abundant silicified anhydrite nodules.

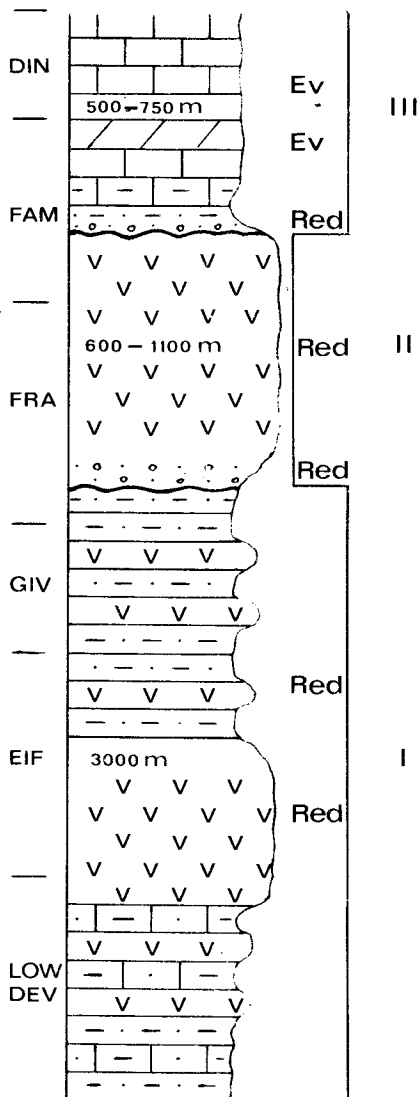


Figure 3

Highly schematized lithostratigraphic column of Devonian-Dinantian deposits in the eastern part of the Ushurakchan and Gydan Zones. Three sedimentary sequences (I-III) are distinguished. Lower Devonian deposits are only known from the eastern part of the Ushurakchan Zone (near Omolon). The figured Eifelian to Middle Frasnian sequence has been recognized in the Gydan Zone (Uvnukeem - Perevalny Valleys). The Late Famennian to Dinantian sequence has been taken from the Ushurakchan (Elergetkhyn Lakes) Zone. Red-coloured deposits (Red) and evaporites (Ev) suggest a warm-arid climate in this area during the Devonian-Dinantian.

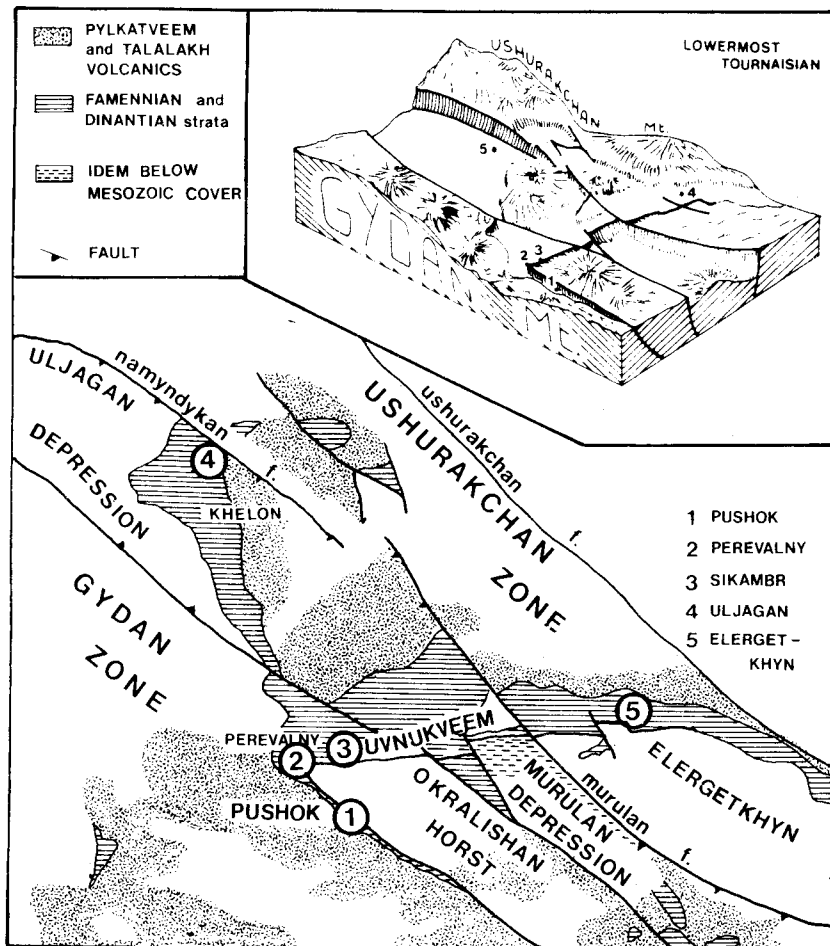


Figure 4. - Geological map of the southeastern part of the Omolon area (redrawn after Simakov *et al.*, 1983; fig. 6) and block-diagram of the considered area during "lowermost Tournaisian" times.

After an observation gap of about 120 m, a coated grain succession (biosparite) has been observed. These Upper Pushok strata are partly dolomitized. Small micritized bioclasts produce a pseudo-pelletoidic texture. Elsewhere coated crinoid ossicles, brachiopod fragments and algae are frequently present.

4.1.2.- Sikambr Formation

Only the lower part of the Sikambr Formation is exposed. It starts with bioosparites grading upwards into an alternation of pelintrasparites, coated grain sequences and intraosparites. The oolites often develop around bioclasts, mainly broken crinoids ossicles. Algal lumps and clasts occur.

4.1.3.- Depositional environment

The base of the Pushok Formation reflects minor deepening events; eventually this resulted in the deposition of biostromal limestones in a subtidal environment. Since these buildups are overlain by sabkha-like sequences their extinction occurred under hypersaline conditions indicating transitory regressions. The overlying Pushok strata display a regressive trend with rhythmic changes from shallow subtidal through in-

tertidal into temporarily restricted supratidal. The Upper Pushok and Lower Sikambr sediments were deposited in a relatively turbulent, open marine shallow subtidal environment (fig. 5).

4.2.- PEREVALNY/SIKAMBR AREA

Eight composite sections give the most complete overview of the Upper Famennian-Tournaisian sequence of the southeastern part in the Gydan Zone. The whole succession, which is up to 700 m thick, is subdivided into four major formations.

4.2.1.- Perevalny Formation

The basal portion of this formation consists of alternating sequences of volcanomict conglomerates, coarse-grained red coloured sandstones and sandy, green coloured shales with intercalated nodular limestones (sandy biosparite). The last lithology type becomes more conspicuous towards younger strata where they may form semi-continuous layers. The conglomerates (with very large pebble-sized volcanogenic fragments) predominate at the base and in the middle part of the formation. The sandstones are composed of sub-rounded to sub-angular, coarse-grained grains

with up to 20% feldspars.

Higher upwards the biosparites alternate with sandy/silty biomicrites which become more prominent towards the top of the formation. Their bioclast content (crinoids, brachiopods, corals, echinoid-spines, ostracodes, . . .), especially the predominance of hashed moravaminids, is distinctly higher than in the underlying limestone intercalations.

Termier *et al.* (1975) assumed that the moravaminids are sponges, while Mamet & Roux (1975) considered these as algae. These sessile organisms, which in their adult stages are cylindrical, tubular, erected and practically always branched, possess a central cavity which may be smooth or irregularly septated. Since moravaminids are loosely stucked, they are easily disrooted by currents. Therefore, they often occur as eroded and redistributed grains. When occurring in situ they form a packstone to baffestone fabric. Some species are ubiquitous in lagoonal deposits (Beauchamp & Mamet, in press). In some Waulsortian buildups, the moravaminid distribution patterns (showing a spatial relationship with sponge spicules) suggest an ecologic environment below the photic limit (Lees *et al.*, 1985). Since comparable observations as reported by the former authors were made in the Omolon strata a similar environment of sedimentation, namely rather deep subtidal, was accepted for the bulk of the moravaminid occurrences.

4.2.2.- Elergetkhyn Formation

This formation is composed of bioclastic carbonates. Different lithologies were distinguished based on various types of bioclasts. The lower and middle portion of this formation consists of pelbiomicrites alternating with nodular biomicrites. The latter bear large amounts of moravaminids (hence the name moravaminid micrites) and crinoids; "Thuringian"-type ostracodes (Bless *et al.*, 1983) occur also. A drastic decrease in the moravaminid content is apparent in the pelbiomicrites, which contain hashed brachiopods, gastropods, corals, ostracodes, bryozoa, foraminifera and sponge spicula. Two dolostone intervals, displaying a xeno- to hypidiotopic fabric, occur. These are secondary in origin. Relic textures indicate that the limestone precursors were pelbiomicrites. Many bentonite intercalations are present in the second dolostone level. Cherts and dolomitized anhydrite nodules (top of bed 11-13, Ustyevo section) occur at the top of the second dolostone unit.

Moravaminid micrites overlain by biomicrites form the upper portion of the Elergetkhyn Formation. Besides the more common bioclasts (crinoids, brachiopods, echinoid-spines, foraminifera and ostracodes) stromatoporoids, algal lumps, Dasycladacea algae and calcispheres are present. Their content increases towards younger strata where they give rise to algal mats and oncomicrite intercalations. A biopelsparite with algal mats and oncolites, overlain by an idiotopic dolostone sequence with silicified anhydrite nodules and fossils, forms the top of the Elergetkhyn Formation. Randomly scattered chert nodules occur throughout this formation. They form an important rock component in the lower portion of the Upper Elergetkhyn Formation and in the uppermost dolostones.

4.2.3.- Mol Formation

This formation starts with thin-bedded, chert-rich bioturbated biosparites grading into biomicrites, both with shale intercalations. Moravaminids are the most abundant biochems in the biomicrites, which also yielded "Thuringian"-type ostracodes.

The Middle Mol strata are composed of a different biomicrite type, in which relics of crinoids, calcispheres, ostracodes and few brachiopods, moravaminids and sponge spines occur. Locally beds with silicified anhydrite nodules are intercalated. Upwards these strata alternate with biopelmicrites and biopelsparites which are practically devoid of moravaminids and sponge spicula. Instead these contain increasing amounts of algal clasts and coated grains. In these strata silicified anhydrite nodules have also been observed.

The upper part of this formation consists of alternating biopelsparites and coated grain sequences. The last sequences are composed of a hash of micritized bioclasts, algal fragments and lumps.

4.2.4.- Sikambr Formation

The lower part of the Sikambr Formation consists of rhythmic sequences of intrabiosparites, peloosparites and oosparites, frequently capped by a thin idiotopic dolostone layer with silicified anhydrite nodules. Higher upward, these dolostones are less developed. Also in upward direction, there is a decrease of the crinoid and brachiopod content in the bioclastic layers, whereas an increase in algal clasts and algal laminite horizons was noticed.

The Middle Sikambr strata are characterized by a succession of algal micrites, semi-continuous silicified anhydrite layers and zebra limestones. In the lower part a limestone breccia, composed of oomicritic and algal micrite fragments occur. Locally, the algal micrites are brecciated and updomed due to the growth of interlayered palisade calcite.

The zebra limestones are characterized by a rhythmic banding on a mm scale. Small fault-like displacements cross-cut these bands. Detailed study has revealed the presence of a rhythmic repetition of three geometric elements corresponding to subsequent crystallization generations. These zebra limestones are identical to the Diagenetic Crystallisation Rhythmites (DCR's) described by Fonboté & Amstutz (1983). The different crystal generations of DCR's are subsequent phases of one and the same process of diagenetic crystallization and recrystallization, in which a differentiation by crystallization fractionation took place. This process occurred under hydrostatic pressure. Since lateral transitions from the Sikambr algal micrites into zebra limestones have been observed both in the field and in thin section, one must accept that the DCR's represent the crystallization products of the algal micrites. Apparently, the first crystal generation (fine-grained, dark-coloured crystal aggregates with inclusions of quartz grains and clays; locally cryptoalgal textures are present) corresponds to the parts richest in organic matter within the algal micrites. This suggests that the crystallization process in these DCR's took place by using preexisting sedimentary structures. The second crystal generation (usually light-coloured) consists of coarse anhedral to subhedral crystals, whereas the locally developed third generation consists of a coarse-grained xenomorphic space infilling.

These zebra limestones occur over a stratigraphical interval of about 35 m, that is interrupted by several observation gaps. Slump structures occur in the uppermost strata.

The Upper Sikambr Formation is composed of pelbiosparites and biosparites, which near the base are thin-bedded and contain silicified and dolomitized anhydrite nodules. Upwards these pass into more massive beds with some cherts. The biochems consist of algal clasts as well as crinoid ossicles, brachiopod fragments, foraminifera, corals, gastropods and few moravaminids. The latter are less common in the youngest strata.

4.2.5.- Depositional environment

The base of the Perevalny Formation reflects a minor deepening event with frequent deposition of clastics in a shallow marine, moderate to high energy environment. The overlying shales with limestone intercalations suggest more uniform subtidal sedimentation conditions, whereas a renewed clastic influx (second major conglomerate/sandstone level) may correspond to a transitory regressive event (fig. 5). The moravaminid micrites near the top of the Perevalny Formation indicate a second, major deepening event where deposition occurred in rather deep subtidal shelf conditions.

Apparent sea level fluctuations may have caused the alternating sequences of moravaminid micrites and biomicrites/pelbiomicrites of the Elergetkhyn Formation, where rather deep subtidal conditions prevailed (fig. 5). The anhydrite pseudomorphs at the top of the second dolostone unit in this formation mark a short regressive event during which the facies changed drastically into shallow subtidal or even supratidal (fig. 5). After a renewed deepening of the depositional environment there was an overall regressive tendency. The regression is reflected by the increased appearance of algal material towards the top of the Elergetkhyn Formation, as well as by the intensively dolomitized and silicified bioclastic limestones with anhydrite relics which eventually occur.

A major deepening event is indicated by the biosparites overlain by moravaminid micrites at the base of the Lower Mol Formation, the last strata being deposited in rather deep shelf environments. This was followed by a regressive trend in the overlying beds which are indicative for more shallow subtidal (bioclastic limestone and coated grain strata) to occasionally intertidal or even supratidal conditions (marked by the presence of anhydrite pseudomorphs).

This regressive tendency continued during the deposition of the Lower Sikambr Formation. The sedimentary sequences which are developed here, reflect minor regressive fluctuations where the sedimentation environment changed from shallow subtidal through intertidal to even supratidal (fig. 5). This regression reached its acme in the middle portion of the Sikambr Formation where algal micrites (wherein abundant

evaporitic relics) indicate sabkha-like sedimentation conditions. The breccia which is present in the lower part of this succession could have an evaporitic collapse origin. The palisade calcite crystals display many features corresponding to the fine primary gypsum crusts described by Schreiber (1978). However, this has to be studied more in detail but the fact that brecciation and updoming is associated with these calcite layers supports this possibility.

The overlying pelbiosparites to biosparites of the Upper Sikambr Formation suggest a renewed transgressive sequence deposited in a shallow subtidal sedimentation environment (fig. 5).

4.3.- ELERGETKHYN AREA

These sections are located in the southeastern Ushurakchan Zone. Here the Upper Famennian - Tournaisian succession is subdivided into five major formations.

4.3.1.- Andylivan Formation

Thin- to thick-bedded nodular biomicrites to pelbiomicrites, often with intensive bioturbation, form the lower part of this formation. These are mainly composed of crinoids, brachiopods (sometimes still in live-position), moravaminids, ostracodes and stromatoporoids. Their clastic content is sometimes high (up to 30 % detritic quartz).

The middle and upper portion of the Andylivan Formation consists of clay-rich, partly silicified biomicrites characterized by a "flaser texture". Apart from some crinoid ossicles, sponge spicules and trilobite fragments, the most important biochems are moravaminids. Pyrite spots, up to several millimeter in diameter, frequently occur.

4.3.2.- Gytgynpylgin Formation

Thin-bedded, intensively silicified biomicrites with a characteristic "flaser texture" also occur in the lower and middle portion of the Gytgynpylgin Formation. Especially in the middle part of the same these alternate with shales. The "flaser texture" is probably produced by traces of worms. Apart from "Thuringian"-type ostracodes and some crinoid ossicles the most important bioclasts are the moravaminids. Locally sponge spicules and trilobite fragments occur. Cherts and pyrite spots are observed throughout the sequence.

Chert-rich, more massive-bedded biomicrites make up the bulk of the Upper Gytgynpylgin Formation. These exhibit an increased bioclast content (mainly crinoids, gastropods and brachiopods).

4.3.3.- Kuluk Formation

The lower part of this formation mainly consists of biosparites composed of an accumulation of hashed crinoid ossicles, brachiopods and ostracodes. Upwards calcispheres and foraminifera are also present. Silicified anhydrite pseudomorphs occur at several levels.

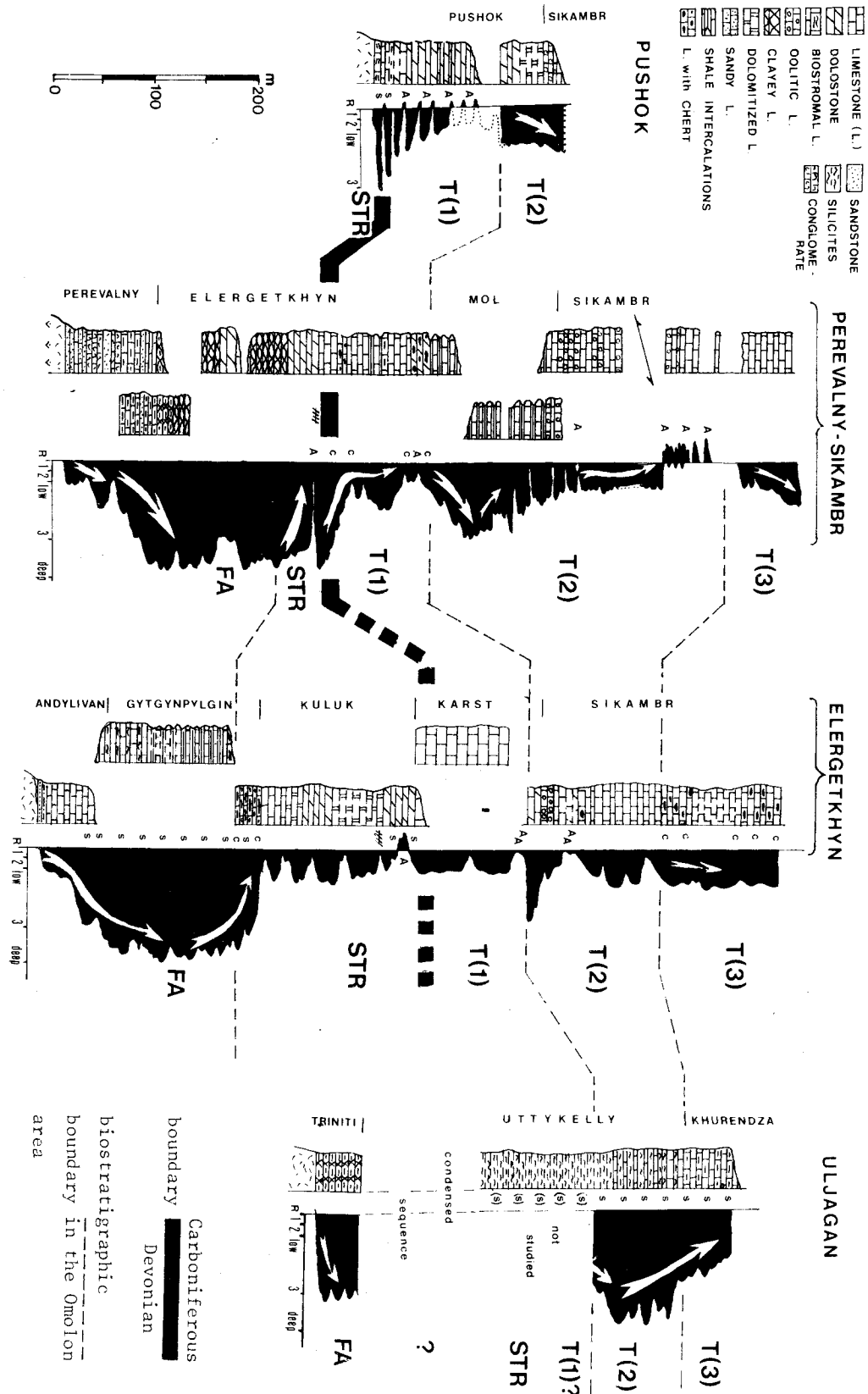


Figure 5. - Variation in depositional environment in the southeastern Omolon area.
 Abbreviations : R. restricted hypersaline supratidal; 1. supratidal; 2. intertidal; 3. subtidal;
 A. major occurrences of anhydrite pseudomorphs; C. major occurrences of chert; S. intensively silicified horizons;
 ### bentonite or tuff occurrences.

These are also found in the overlying (Fe-rich) xenotopydrotic dolosparites (grainsize : 120-150 μm). The crystals are often impure and zoned. Locally, a moldic porosity is created by selective leaching of bioclasts. Two volcanic tuff horizons (1.5 to 2 m thick) are concordantly intercalated in these dolostones. The top of this formation is formed by a breccia, composed of chert, silicified anhydrite and dolostone fragments in a matrix of heterogeneous dolosparite and calcite spar.

4.3.4.- Karst Formation

The lower and middle part of the Karst Formation consists of a biosparite, mainly composed of an accumulation of micritized crinoid ossicles, calcispheres, foraminifera, brachiopod fragments and silicified stromatoporoids. Locally algal and oncolite-rich beds occur, giving rise to biooncosparites. These strata are often completely recrystallized. An intensively weathered dolostone-limestone sequence with several relics of anhydrite pseudomorphs forms the upper portion of the formation. The top of the same consists of a packstone/boundstone composed of stromatoporoids and brachiopods.

4.3.5.- Sikambr Formation

The base of the Sikambr Formation consists of alternating bioosparites and biointrasparites. The oolites often are millimeter-sized and are embedded in a partly silicified cement. The bioclasts are frequently micritized yielding a coated grain succession. These strata are overlain by an intensively weathered sequence of dolostones and limestones with silicified anhydrite nodules.

Oosparites, oncosparites and intrabiosparites characterise the middle part of the Sikambr Formation. The oolitic and oncolitic sequences are often associated by coated bioclasts (crinoid ossicles, brachiopods and some foraminifera). Locally these intervals are dolomitized. Apart from few chert nodules, also a continuous chert layer occurs in the middle part of the formation.

Within the upper portion of this formation a coated grain succession (intrabiosparite) with algal clasts was found. The uppermost strata are relatively rich in chert, especially near dyke intrusions.

4.3.6.- Depositional environment

The Andylivan Formation reflects a prolonged deepening event with deposition in open marine, shallow subtidal (nodular biomicrites to pelbiomicrites with stromatoporoids and sometimes high clastic content) to deep subtidal shelf conditions (moravaminid micrites; fig. 5).

These rather deep subtidal shelf conditions also controlled deposition of the Lower and Middle Gytgynpylgina strata (moravaminid micrites with "Thuringian"-type ostracodes, sponge spicules and trilobites). Upward-shallowing in the Upper Gytgynpylgina

Formation is marked by an increased and more diversified bioclast content (fig. 5).

This apparent fall of sea level continued during deposition of the Kuluk Formation. The basal biosparites indicate a shallow subtidal environment. Fluctuations towards very shallow subtidal and even supratidal conditions are reflected by beds with anhydrite relics. This regressive tendency reached its acme during the deposition of the uppermost Kuluk Formation (fig. 5), where a breccia with abundant silicified anhydrite fragments points to restricted hypersaline conditions. The breccia may have an evaporitic solution collapse origin. A minor deepening event at the base of the Karst Formation resulted in an open marine, shallow subtidal environment (with deposition of biosparites). Minor sea level fluctuations are reflected by the oncolitic horizons which suggest intertidal to supratidal conditions. The interval with anhydrite pseudomorphs near the top of this formation indicates a transitory sea level fall. The overlying packstone/boundstone sequence at the top of the same points to a subtidal sedimentation environment reflecting a major deepening event (fig. 5).

Open marine subtidal shelf conditions continued during deposition of the Sikambr sediments. Several sea level fluctuations (resulting in transitory shallowing of the environment) are reflected by the intercalated oolitic and oncolitic intervals, as well as by the beds with anhydrite relics occurring slightly above the base of the Sikambr Formation.

4.4.- ULJAGAN SECTIONS

This sedimentary sequence formed in a graben-like fault-bounded depression along the flank of the Ushurakchan Zone (fig. 4). This sequence is subdivided into three lithologic units.

4.4.1.- Trinity Formation

This formation consists of nodular limestones alternating with black, silicified shales. These strata display similar features as the so-called "Souverain-Pré" beds in Belgium. This formation has not been studied in detail.

4.4.2.- Uttykelly Formation

The lower and middle portion of this formation has not been studied in detail. It consists of phtanites and black, silicified shales with isolated lenses and nodules of limestone. These sediments resemble the silicified "Kulm" shales of the Ruhr basin in the Federal Republic of Germany.

The Upper Uttykelly Formation starts with pelbiosparites grading into biosparites. Locally gray to green coloured shales are intercalated. Bioturbation phenomena and "flaser-structures" (probably produced by worm-traces) are common. Crinoid ossicles form the

most important biochems. Also echinoid spines, bryozoa, ostracodes and sponge spicules occur. Radiolarian-like silica spherulites have been observed, although definitive identification is impossible because diagnostic features have been obliterated by recrystallization.

4.4.3.- Khurendza Formation

This unit is composed of well-bedded, poorly silicified crinoidal limestones with brachiopods and bryozoa.

4.4.4.- Depositional environment

The nodular limestones of the Trinity Formation have been deposited in a rather deep subtidal environment. Since these overly volcanomict conglomerates and sandstones on top of volcanites, a major deepening event must have occurred at the base of the Trinity Formation (fig. 5). Similar deep subtidal conditions may have persisted during most of the time of the deposition of the Utykely beds, where crinoidal limestones may reflect transitory shallowing of the environment.

Presumably, an overall regressive trend marks the deposition of the crinoidal limestones with brachiopods and bryozoa of the Khurendza Formation. Here, deposition seems to have been controlled by more shallow subtidal conditions (fig. 5).

5. - UPPER FAMENNIAN-TOURNAISIAN TRANSGRESSION-REGRESSION CYCLES

The repeated deepening and shallowing of the marine depositional environment in the southeastern Omolon area have been dated mainly by foraminifera and conodonts (Simakov *et al.*, 1983; Shilo *et al.*, 1984). Even taking into account that the foraminifer and conodont assemblages are partly endemic, a rather detailed correlation with several areas around the Old Red Continent can be established. In this way it is possible to compare some of the main deepening and shallowing events in the Omolon area with "reknow" eustatic sea level fluctuations elsewhere (e.g. Johnson *et al.*, 1985).

The beginning of the Upper Famennian transgression has been dated by means of conodonts to occur in the *terminalis* or *semicostatus* local conodont zones. These have been correlated by Gagiev (*in* Shilo *et al.*, 1984) with the former *velifer* zone which corresponds to the Uppermost *marginifera* and *trachytera* zones of Ziegler & Sandberg (1983, 1984). Accepting this correlation as correct, the transgression (T) start in the Omolon area (fig. 6) may be the time equivalent of the T start at the base of the Lower *trachytera* Zone in the western USA and in the western Canada (Johnson *et al.*, 1985).

Upward shallowing of the sedimentary facies has been observed in the Perevalny succession somewhere

in between the *obliquicostatus* and *extralobatus* local conodont zones. This regression may be placed somewhere in the *postera* conodont Zone of Ziegler & Sandberg (1983, 1984).

The second start is marked by a renewed transgression in the Perevalny Valley and by an increased deepening of the shallow subtidal environment in the Elergetkhyn (Gytgynpylgyn) sections. In both cases this T start occurs somewhere between the *obliquicostatus* and *extralobatus* local conodont zones. It seems obvious to correlate this event (fig. 6) with similar sea level rises at the base of the Lower *expansa* conodont Zone in North America (Johnson *et al.*, 1985). During this second T-R cycle a rather deep marine shelf environment developed.

This is marked by nodular limestones (sometimes with cherts) and alternating shales and limestones, both containing abundant moravamminids and "Thuringian"-type ostracodes.

The Strunian and Lower Tournaisian strata in the Perevalny/Sikambr and Elergetkhyn successions show important differences in the relative depth of the depositional environment. Sedimentation in the Pushok area started during this timespan (fig. 5). These indicate differential downwarp of the basement during that time interval. Mobilisation of the fault zones during this period is suggested by volcanogenetic rocks on top of strata belonging to the *extralobatus* local conodont zone (presumably equivalent of the Upper *expansa* zone, or Fa2d-Tn1a in Belgium). Features such as the intensively dolomitized, chertified and/or silicified character of the strata occurring around the Devonian-Carboniferous boundary along the E-W trending Uvnukevem fault (fig. 4), as well as the occurrence of trace mineralizations (sphalerite galena, pyrite, . . .) suggest fault mobilization with exhalation of (mineralizing) solutions. This interpretation is also argued by lithogeochemical data (Swennen *et al.*, 1986). The depositional depths during this period, however, seem to have been usually less important than during the second (*expansa*) deepening event. This encompasses similar phenomena in North America and western Europe.

A third important deepening of the sedimentary environment occurred at the beginning of the Middle Tournaisian in the Sikambr, Elergetkhyn and Uljagan successions (fig. 6). Moravamminids and "Thuringian"-type ostracodes characterize the deep shelf facies at Sikambr (fig. 5). This event corresponds to the *quadriplicata* local conodont Zone which is correlated with the Lower *crenulata* conodont Zone of western Europe and North America (Sandberg *et al.*, 1983). This rather short-lived deepening event is followed by an overall upward-shallowing of the environment during the higher Middle Tournaisian and Upper Tournaisian, marked by minor fluctuations of the apparent sea level.

The described correlations indicate that the major transgressions of the Late Famennian and Middle Tournaisian as documented around the western and southern

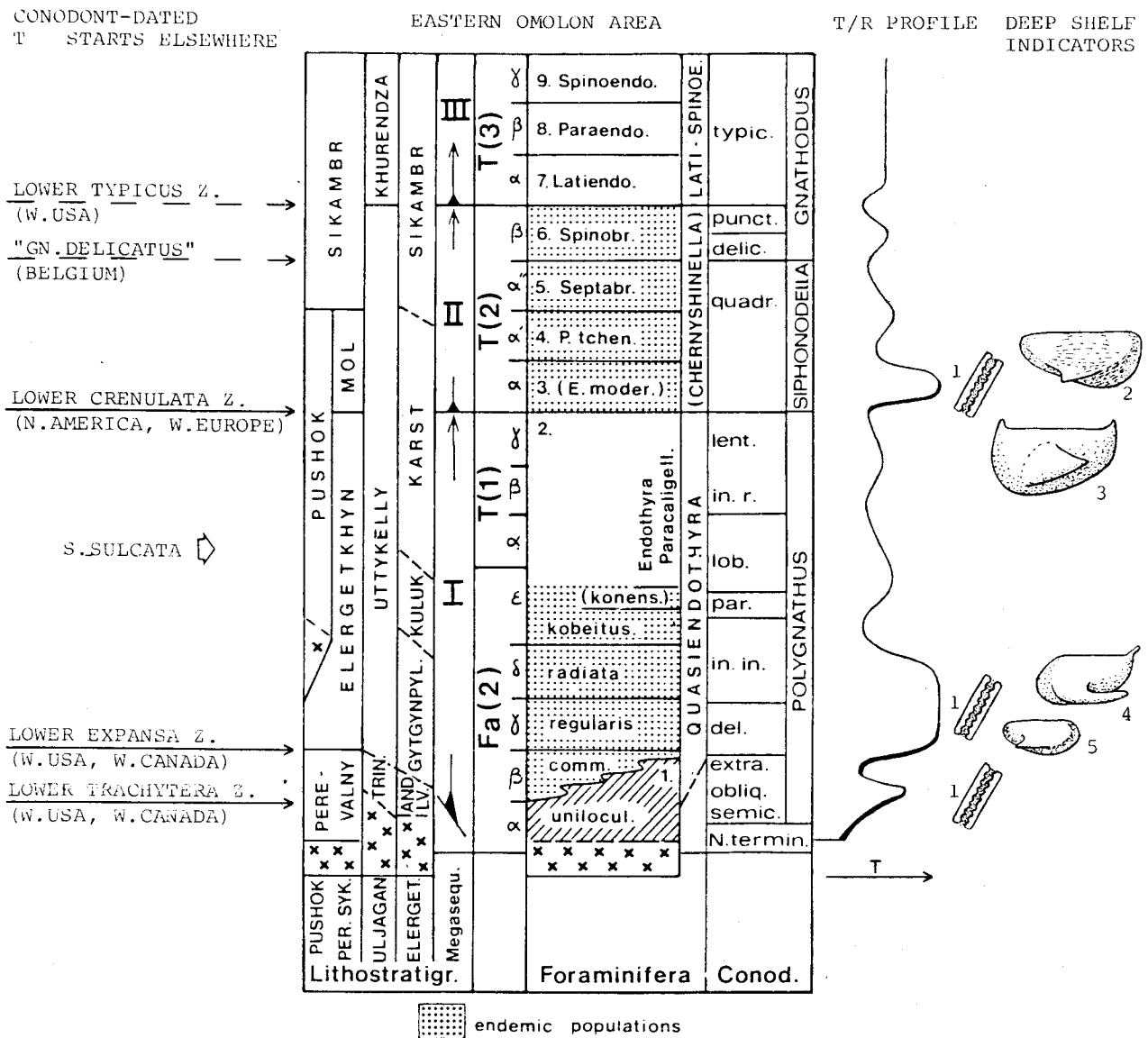


Figure 6. - Litho- and biostratigraphic subdivisions of the Upper Famennian and Tournaisian deposits in the southeastern Omolon area (from Simakov *et al.*, 1983; Shilo *et al.*, 1984), compared with the T/R profile and the occurrence of deep subtidal shelf indicators, and with some selected, conodont-dated T/R starts elsewhere. Also the lower boundary of the *Siphonodella sulcata* conodont Zone is shown. Deep shelf indicators: 1. Moravamminid; 2 - 5. "Thuringian"-type ostracodes with lateral spines.

margins of the Old Red Continent can also be detected in the southeastern part of the Omolon area. The overall eustatic regression during the Strunian and Lower Tournaisian, however, is partly by masked differential down-warp, notably in the Perevalny Valley.

6. - CONCLUSIONS

The sedimentary facies of the Upper Famennian to Upper Tournaisian deposits vary from deep marine shelf (shales and limestones with an impoverished benthos of moravamminids and with "Thuringian"-type ostracodes) through shallow marine subtidal shelf (bioclastic limestones with a rich and diverse benthos including

corals, brachiopods and multilocular foraminifera, oolitic limestones, . . .) into intertidal to supratidal environments (early-diagenetic dolomites, micrites and evaporite relics).

The intricate lateral and vertical facies changes suggest repeated eustatic sea level fluctuations partly masked, retarded or prolonged by differential tectonic movements of the block-faulted basement in the southeastern Gydan - Ushurakchan Zones. Three major Transgression-Regression (T/R) starts within the considered Omolon area correlate with T/R starts elsewhere, namely with the:

1. Lower *trachytera* Zone (W. USA, W. Canada)
2. Lower *expansa* Zone (W. USA, W. Canada)
3. Lower *crenulata* Zone (N. America, W. Europe).

Differential downwarp of the basement resulted in apparent sea level fluctuations, especially during the Strunian and Lower Tournaisian. During this timespan important fault activity occurred in the southeastern Omolon area along the Uvnukveem fault. In association with this fault activity it came to the exhalation of (mineralizing) solutions.

7. - ACKNOWLEDGEMENTS

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