A C T A P A L A E O N T O L O G I C A P O L O N I C A
Vol. 24 1979 No. 2

KRZYSZTOF MAŁKOWSKI and ANTONI HOFFMAN

SEMI-QUANTITATIVE FACIES MODEL FOR THE KAPP STAROSTIN FORMATION (PERMIAN), SPITSBERGEN

MAŁKOWSKI K. and HOFFMAN A. 1979. Semi-quantitative facies model for the Kapp Starostin Formation (Permian), Spitsgerben. — Acta Palaeont, Polonica, 24, 2, 217—230, June 1979.

Biotic and abiotic rock constituent of the Kapp Starostin Formation (Permian), South-West Spitsbergen, have been studied by means of factor analysis of correspondences. Eight associations are distinguished among the variable (thick-shelled brachiopod, bryozoan, brachiopod-crinoid, bryozoan-ostracode, sponge-ostracode, sponge, foraminifer-algal, and foraminifer associations) and interpreted as indicative of distinct facies zones including nearshore, offshore trough, bank, open sea, and lagoon. The facies pattern was controlled mainly by distance from the shoreline, coast type, water energy and depth.

K e y w o r d s: biofacies, factor analysis, Permian, Spitsbergen.

Krzysztof Małkowski, Zakład Paleobiologii, Polska Akademia Nauk, Al. Żwirki i Wigury 93, 02-089 Warszawa, Poland. Antoni Hoffman, Wiejska 14 m. 8, 00-490 Warszawa, Poland. *Received: August 1978.*

INTRODUCTION

The biota and lithology of the uppermost Paleozoic of South-West Spitsbergen were studied by one of us (K. M.) in the course of three successive (1974 to 1976) Polish Paleontological Expeditions to the Spitsbergen [1]. The investigated area lies between Hornsund and Isfjord, and detailed observations were made on sections at Treskelen, Hyrnefjellet, Triasnuten, Polakkfjellet, Reinodden, Ahlstrandodden, and Kapp Starostin (Festung-profil) (fig. 1). The sediments and fauna are from the Kapp Starostin Formation (Permian) of Burov *et al.* (1965); see also Cutbill and Challinor (1965). The lithology and stratigraphy of the Kapp Starostin Formation were previously studied by Frebold (1937), Orvin (1940),

[1] The expeditions were organized by the Institute of Paleobiology (former Institute of Paleozoology) of the Polish Academy of Sciences, under the leadership of Professor K. Birkenmajer (1974) and Professor G. Biernat (1975, 1976).

Forbes *et al.* (1958). The southern range of the formation, in the Hornsund area, was described by Birkenmajer (1964), Birkenmajer and Logan (1969). The formation consists mainly of cherty rocks and some limestones; their petrology was studied by Siedlecka (1970) who discussed also their sedimentary environment. Some of its biotic components were also investigated in detail; brachiopods, by many authors, lately by Birkenmajer and Czarniecki (1960), Birkenmajer and Logan (1969), Gobbett (1963) and Sarytscheva (1977), bryozoans by Małecki (1968 and 1977),

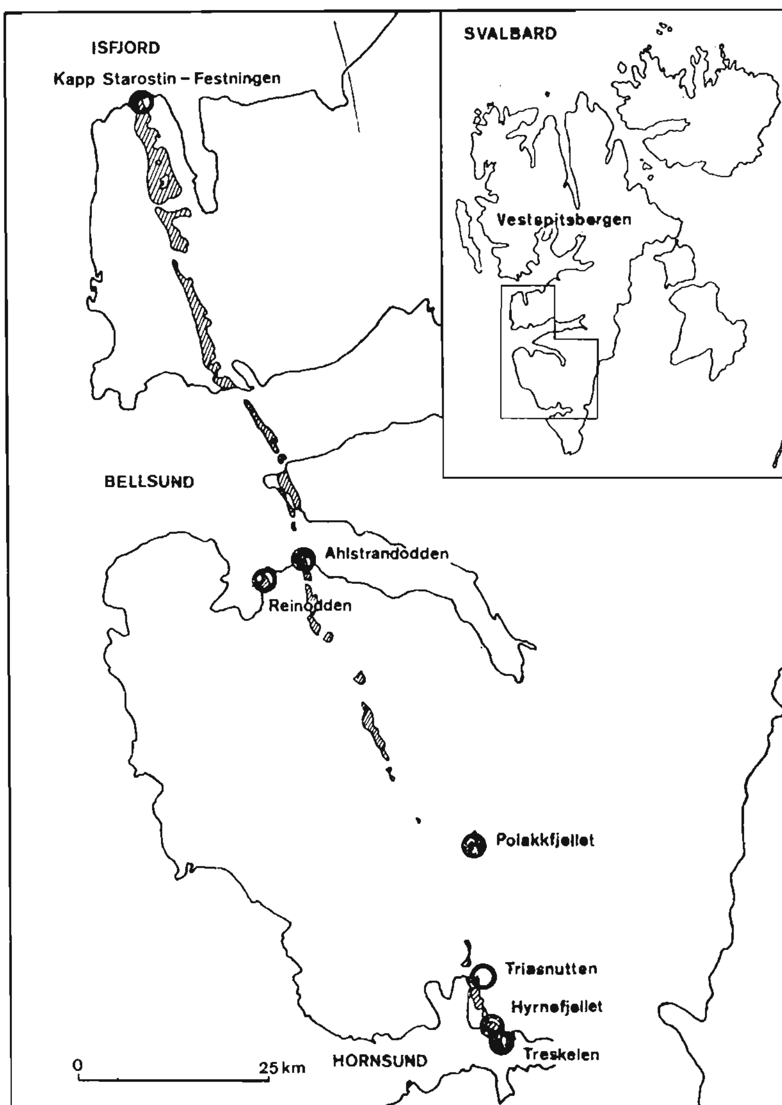


Fig. 1. General map of Svalbard with the location of investigated profiles.

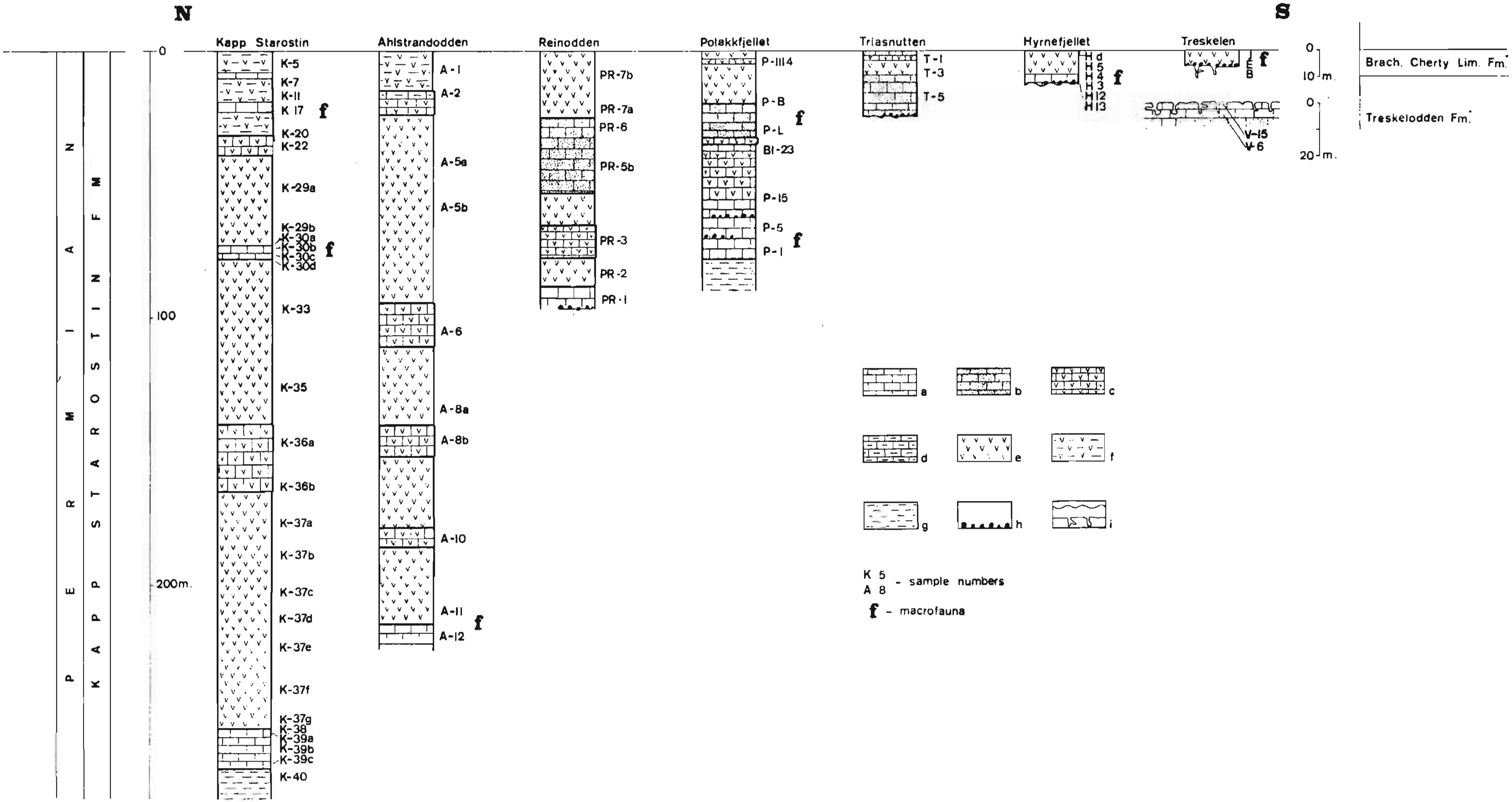


Fig. 2. Investigated geological sections of the Kapp Starostin Fm. and the part of Treskelodden Fm. (Vestspitsbergen) with marked sampled places. *a* limestone, *b* sandy limestone, *c* cherty limestone, *d* marly limestone, *e* chert, *f* cherty marl, *g* marl, *h* pebbles and granules, *i* disconformities.* Brach. Cherty Lim. Fm. and Treskelodden Fm., after Birkenmajer (1964).

sponges by Siedlecka (1970), foraminifers by Sosipatrova (1967) and bivalves by Frebold (1937). The age of the Kapp Starostin Formation was discussed by Ustritsky (1967, 1972), Stiepanov (1957, 1973) and Szaniawski and Małkowski (1979). The aim of this paper is to analyse the habitat and taphonomy of the fauna which, it is hoped, will provide a general facies framework for future stratigraphic and paleobiologic studies.

The material studied consists of lithological descriptions of complete geological sections (fig. 2), two hundred thin sections, additional micropaleontological samples, and macrofaunal collections from the most fossiliferous beds. The data derived from the thin sections and micropaleontological samples were studied by factor analysis of correspondences, which revealed the interrelationships among various biotic and abiotic rock constituents. (The computer input set is available in table form from the senior author). The statistical analysis was performed with the use of the CYBER computer at the computing center of the Polish Academy of Sciences, Warsaw. The facies model based upon the results of this analysis has also been supplemented with data on the macrofauna, and the lithological succession.

Acknowledgements: An anonymous reviewer is gratefully acknowledged for criticism against an earlier draft of the paper. Our thanks are due to Mrs D. Sławik and Mr T. Krasnodębski for the text drawings and to Mrs E. Wyrzykowska for the photos.

FACTOR ANALYSIS

In order to recognize distributional patterns of the fauna in the Kapp Starostin Formation, relative abundances of the most important benthic components of the biota were determined in semi-quantitative terms (absent = 0, present = 1, rare = 2, common = 3, very common = 4, abundant = 5). We feel, however, that a purely actualistic approach to paleoecology of Paleozoic faunas may be inadequate and therefore, we categorized the fauna into broad morphological groups which we considered to have had similar ecological requirements. Such a categorization of the biota was also required by the very nature of the data set consisting mostly of thin sections, as any precise identification of macrofossils is usually impossible under a microscope. Some of the morphological categories are actually taxonomic units of various rank (genus to phylum), while the others are based purely on morphology (e.g. ornamented ostracodes or large-sized thick-shelled brachiopods). The classification system is taxonomically heterogeneous but nevertheless, we believe that the particular classes are ecologically coherent and hence, the results may be environmentally meaningful (cf. Park 1968). To provide independent evidence for the environmental interpretations, the inorganic rock constituents were also studied semi-quantitatively.

The following biotic and abiotic categories were used in the analysis:

- algae (abbreviated as ALGA in Tables 1 and 2);
- foraminifers: *Ammodiscus* (AMMO), *Ammovertella* (INKR), *Earlandia* (PROS), *Endothyra* (ENDO), *Eofusulina* (EOFU), *Frondicularia* (FRON), *Geinitzina* (GEIN), *Glomospira* (GLOM), *Nodosaria* (NODO), *Schubertella* (SPIR);
- sponges (SPIC);
- brachiopods: large-sized thick-shelled (mostly productoids, BRDG), large-sized thin-shelled (linoproductids and some spiriferoids, BRDC), medium-sized thick-shelled (mostly spiriferoids, BRSG), medium-sized thin-shelled (some productoids, spiriferoids, and rhynchonelloids, BRSC), small-sized (some productoids, spiriferoids, rhynchonelloids, and dielasmataceans, BRMA);
- bryozoans: amplexoporoids (MSTR), fenestelloids (MSFE), timanodictyoids (MSIN);
- ostracodes: ornamented (MAOR), non-ornamented (MAGL);
- gastropods (SLIM);
- crinoids (CRIN);
- amorphous silica (SIO2);
- clay (IL);
- sand (PIAS);
- gravel (ZWIR);
- glauconite (GLAU);
- unidentifiable bioclasts (BIO);
- pellets (PEL);
- micrite (MIKR);
- sparite (SPAR).

These data were subsequently studied by means of the R-mode factor analysis of correspondences (cf. Benzécri 1973), the results of which are given in Table 1.

The first seven factor axes account for some 60% of the total variability of the data set, the first axis accounting for but 18.2% and the second one for 10.3% of the variability (Table 1). Thus, the factor-spatial relationships among the variables appear rather complex. Furthermore, the quality of representation of many variables is very poor (e.g. *Ammodiscus*, ostracodes, gastropods). Therefore, presence-absence data on the biotic categories alone were also studied by means of the R-mode factor analysis of correspondences (Table 2) in order to test the constancy of associations among the variables. Both the analyses yielded almost the same associations thus, demonstrating their consistency and meaningfulness.

Three distinct mega-associations can be easily recognized in both the

Table 1

R-mode factor analysis of correspondences of biotic and abiotic rock constituents of the Kapp Starostin Formation (relative—abundance data); factor matrix. The variables are grouped accordingly to their loadings. For explanation of the symbols see the text.

	Quality of represen-tation max = 1000	I axis	II axis	III axis	IV axis	V axis	VI axis	VII axis	Mega-associa-tion	Asso ciation
SPIC	773	−1356	440	−184	−146	−185	−35	−16	sponge dominated	sponge SS
SiO_2	890	−1391	454	−184	−135	−178	59	−15		
IL	690	−1004	110	−3	102	148	89	54		sponge — ostracode SO
MAOR	119	−682	483	−59	−45	23	−301	227		
MAGL	76	−329	151	−56	−199	327	−424	216		
NODO	128	−352	343	78	19	151	−7	205		
FRON	144	−352	−73	355	−281	410	−256	−229		
MSFE	160	−141	134	531	−271	249	−365	−63	brachiopod dominated	bryzoan BB, BO
MSTR	503	256	−315	728	−536	224	−251	4		
MSIN	291	146	−238	549	−488	155	−446	164		
BIO	715	491	−98	337	−228	−106	−47	−15		
BRDG	335	−47	−640	895	−91	529	−381	−740		thick— —shelled brachiopod BT
BRSG	413	192	−385	723	−57	370	−331	−902		
BRDC	135	581	−463	−324	−314	−979	−191	394		brachiopod — crinoid BC
BRSC	341	345	−86	33	−221	−596	160	367		
BRMA	47	291	−2	256	−51	141	19	87		
CRIN	410	739	−68	44	−238	−190	6	187		
ZWIR	987	165	−1626	−3384	−914	−49	−2563	−303		
PIAS	959	−131	−1272	−175	812	−18	336	27		
GLAU	312	−753	−1463	−55	1400	169	888	−252		
INKR	699	1099	1278	−475	1329	−1273	−268	−14		foraminifer — algal FA
ALGA	692	954	1165	−433	1294	−1564	−375	519		
GEIN	397	396	517	−821	−267	822	148	−726	foraminifer dominated	foraminifer FF
ENDO	712	1001	921	−727	−570	−176	−301	−897		
GLOM	221	922	584	−503	−21	94	506	−316		
EOFU	561	1233	1446	−591	729	218	643	−3175		
SPIR	520	1200	1598	−502	1118	1012	223	−3163		
PROS	417	1148	1059	−738	229	367	1277	−3602		
AMMO	44	408	793	−399	168	204	294	25		
PEL	898	1045	327	−1885	−1118	1639	1675	750		
MIKR	847	811	574	101	559	567	−270	425		
SPAR	790	778	−164	−70	−910	−861	643	−139		
SLIM	149	165	526	66	109	242	−301	−203		
Variability percent accounted for by the axes		18,2	10,3	8,4	7,6	6,0	5,4	4,5		

Table 2

R-mode factor analysis of correspondences of the biota of the Kapp Starostin Formation (presence—absence data); factor matrix. The variables are grouped accordingly to their loadings. For explanation of the symbols see the text.

	Quality of representation (max = 1000)	I axis	II axis	III axis	IV axis	V axis	VI axis	VII axis
SPIC	990	1149	1663	−1040	−540	−250	184	69
MAGL	532	344	304	618	568	116	−482	223
MAOR	491	406	840	853	1104	−111	33	503
NODO	431	331	422	330	321	445	−261	−192
FRON	432	601	116	492	−98	479	−506	9
MSTR	624	510	−836	−138	−219	−3	335	59
MSFG	262	394	−138	201	222	−112	639	−55
MSIN	408	492	−538	−43	107	−117	358	−472
BRDG	714	736	−890	107	−1259	530	−218	663
BRSG	425	389	−512	198	−764	194	−415	−82
BRDC	427	−497	−565	−1214	989	−698	−1377	597
BRSC	507	−194	−141	−727	443	−438	−255	261
BRMA	182	115	−430	−234	−44	−241	−218	−539
CRIN	615	−266	−623	−477	381	−343	−83	145
INKR	592	−1565	367	−354	31	693	218	−120
ALGA	816	−1834	339	−745	−197	1085	56	−153
GEIN	536	−100	277	798	−96	−447	−535	−617
EOFU	613	−1649	567	969	−944	−1620	735	798
SPIR	480	−1300	458	1096	−746	−1402	405	936
PROS	555	−1267	423	1513	−1814	−2745	−426	−1105
ENDO	709	−1368	284	83	−326	−22	−207	81
GLOM	427	−1133	229	−88	−312	665	−97	−390
AMMO	563	−293	149	866	208	921	1138	2526
SLIM	612	−43	17	257	332	90	1086	−394
Variability percent accounted for by the axes		14.8	10.5	8.1	6.8	6.4	6.0	4.8

factor matrices: the sponge, brachiopod, and foraminifer dominated ones. The sponge dominated mega-association is closely related to the abundance of amorphous silica and clay. It can be split into two distinct associations, namely the sponge-ostracode association with *Nodosaria* and *Frondicularia*, and the other one dominated by sponges alone. The brachiopod dominated mega-association is closely related to the abundance of bioclasts; it is also weakly correlated with the amounts of terrigenous matter (sand and gravel) and glauconite. It can be split into three distinct associations dominated by bryozoans, thick-shelled brachiopods, and brachiopods and crinoids. The fenestelloid bryozoans are most closely linked with the other bryozoans but actually, they appear intermediate between the brachiopod and sponge dominated mega-associations. The foraminifer dominated mega-association is strongly correlated to the amounts of pellets, micrite, and sparite. It can be easily split into two distinct associations, namely the foraminifer (*Ammovertella*) — algal association and the other one dominated by foraminifers alone (*Earlandia*, *Endothyra*, *Eofusulina*, *Glomospira*, and *Schubertella*). Both *Geinitzina* and *Ammodiscus* appear unique in their distribution patterns among the foraminifers of the Kapp Starostin Formation, even though they are related to the foraminifer dominated mega-association. The gastropods do not form part of the three mega-associations; this may, however, be an artifact of the analysis, as the quality of their representation is very poor.

The associations are recognized as indicative of seven main biofacies of the Kapp Starostin Formation: sponge (marked SS in figs 3 and 4), sponge-ostracode (SO), bryozoan (BB), thick-shelled brachiopod (BT), brachiopod-crinoid (BC), foraminifer-algal (FA), and foraminifer (FF) biofacies (pls 2, 3). The weakly expressed association of fenestelloid bryozoans, ostracodes, and brachiopods can also be regarded as indicative of the additional bryozoan-ostracode (BO) biofacies. The R-mode factor-analytic solution produced by the use of the algorithm of Benzécri (1973) is analogous to the Q-mode solution of a given data matrix. Therefore, the Q-mode analysis of the relative-abundance data on the most important biotic and abiotic rock constituents of the Kapp Starostin Formation was also undertaken, permitting assignment of every sample to a definite biofacies (fig. 4). On the other hand, one may interpret this biofacies classification in environmental terms basing upon the R-mode analysis.

The first factor axis is determined mainly by the sponges, clay, and amorphous silica; and on the other side by the brachiopods, bryozoans, algae, foraminifers (exclusive of *Nodosaria* and *Frondicularia*), and various carbonate components. One may suppose that this axis represents a turbulence gradient with the maximum abundance of sponges indicative of the most sheltered areas. This axis may also reflect a gradient in water depth, as the algae are obviously indicative of the photic zone. The second factor axis is determined by the successively increasing loadings of gravel, sand and glauconite, clay, silica, and micrite. It may be interpreted as reflecting a gradient in type and intensity of terrigenous influx to the depositional environment which in turn, implies a gradient in distance from the shoreline and/or a variability in the coast type. The next five factor axes represent highly complex interrelationships among the variables and appear hardly interpretable in environmental terms.

FACIES MODEL

One may conclude that a simple facies model reflecting the environmental controls upon the biofacies distribution in the Kapp Starostin Formation arises from the factor analysis. The life environment of a fossil assemblage may obviously differ from the final-burial environment. Nevertheless, one may claim that some features of the original biofacies are usually preserved *in situ* and therefore, the term biofacies can be used.

The facies-model construction involved the following lines of argument: The gradient in distance from the shoreline was determined using Allen's (1967) premise of a change in terrigenous-matter type with increasing distance from a shoreline. One has, however, to take into account the possibility of local modifications resulting from current pattern, bottom relief, and/or coast type. Such an inference from a clastic component may or may not be confirmed by an analysis of the associated biotic constituents (cf. Bendict and Walker 1978), especially with respect to their preservation, spatial distribution, and orientation. Paleozoic fossil assemblages cannot be interpreted directly in environmental terms because of the limits of an actualistic methodology. Nevertheless, morphological characteristics of some organisms such, as the shape and thickness of their skeletons may sometimes be regarded as indicative of the original water energy. On the other hand, the mode of preservation of fossil remains (mostly their fragmentation and orientation) can be used to determine the energy level of their final-burial environments during transportation or deposition (cf. Johnson 1960). The presence of algae *in situ* was regarded as indicative of photic conditions. The autochem type ($CaCO_3$ or SiO_2) made possible a determination of regime relative to the critical point ($pH = 8$) of their solubility, provided that processes of concentration of silica is synsedimentary (Siedlecka 1970). The redox conditions below the sediment/water interface were estimated after the presence or absence of pyrite and bituminous matter. All these premises permitted an estimation of the relative water-depth in particular facies zones.

On this basis, the computed facies of the Kapp Starostin Formation were assigned to various positions along a nearshore to open sea transsect (fig. 3a, b). The facies types were also dependent upon the adjacent coast nature (high versus low coast) controlling in part the terrigenous influx and water dynamics. In fact, transgressive character of both the Kapp Starostin Formation itself (fig. 2) and the underlying Gipshuken Formation (Orvin 1940, Birkenmajer 1964, Winsenes 1966) may allow to draw some conclusions about land proximity and its nature at their deposition time.

The recognized facies zones can be briefly characterized as follows: Large amounts of coarse clastic matter (pebbles and granules) were typical of an extremely shallow, nearshore area in proximity of a high coast (zone I). The oxygen content and nutrient supply were high but the most specific feature of the environment was its high energy level (at least temporarily). The environment was inhabited mostly by large-sized thick-shelled productoids able to anchor strongly in a sediment owing to

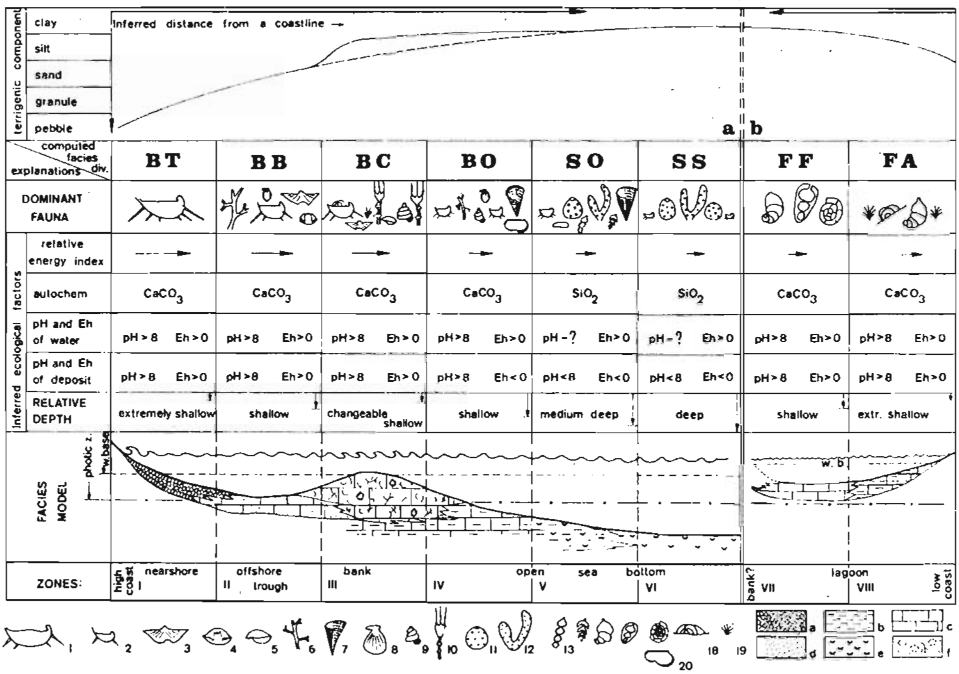


Fig. 3. The facies model of the Vestspitsbergen Permian sea. Distance from a coastline inferred from the grain size curve (the dashed segment of the curve is appropriate if there is no bank).

1 large-sized thick-shelled brachiopods, *2* medium- and small-sized productoids, *3* spiriferoids, *4* rhynchonelloids, *5* dielasmataceans, *6* bryozoans: amplexoporoids and timanodictyoids, *7* bryozans: fenestelloid, *8* bivales, *9* gastropods, *10* crinoids, *11* massive sponges, *12* tubular sponges, *13—18* foraminifers (explanations in the text), *19* algae, *20* ostracodes.

Lithology: *a* pebbles and granules, *b* silt, *c* lime mud, *d* sand, *e* silica clay, *f* coquina.

their long and thick spines. However, even those brachiopods appeared unable to resist the strongest currents occurring episodically and loaded with coarse clastic particles. This resulted in fragmented thick-shelled brachiopods commonly occurring in gravel. Some brachiopod shells are filled with micrite which may indicate that their original biotope was quieter than their burial environment. One may claim that the thick-shelled productoids lived in some shelters disturbed occasionally (judging from the large size of individuals) by catastrophic storms or changes in shoreline configuration.

A more offshore shallow area (zone II) was settled by a rich organic assemblage dominated by thick-branched amplexoporoid and timanodictyoid bryozoans and mostly medium-sized productoid, spiriferoid, and rhynchonelloid brachiopods of highly variable mode of life. The fossil remains appear sometimes redeposited but never to any considerable extent. The bryozoan colony shapes may indicate their ability to resist a considerable water turbulence (Schopf 1969) even though the energy index was probably lower than in the nearshore zone. The sandy substrate was sufficiently stable for the proliferation of sessile benthic animals. Because this zone borders seawards upon a bank (see below), the environment may have been an offshore trough.

The most distinctive characteristic of the next successive facies zone (III) was large amounts of biogenic matter in the sediment. The state of preservation of the fossils is highly variable, ranging from very good to strongly fragmented and locally mixed. The fossil assemblage is dominated by crinoids, medium- and small-sized productoid, spiriferoid, rhynchonelloid, and dielasmatacean brachiopods, gastropods, and structures of possible algal nature. Thus, the environment must have been well oxygenated, within the photic zone, and rich in nutrients. The terrigenous matter occurs rather sparsely but it may occasionally become fairly abundant indicating a land proximity. We consider that the environment was a bank of low relief above the sea bed.

The marly-clayey sediments of facies zones IV to VI comprise low-diversity fossil assemblages dominated by sponges. The low diversity fauna is thought to be the result of a fluid muddy substrate and variable pH regime nevertheless, the ostracodes and nodosarian and frondicularian foraminifers did apparently cope well with these ecological conditions. The occurrence of such fragile organisms as some thin fenestelloid bryozoans and certain sponges indicates that the water turbulence was low. We interpret the zones IV to VI to range from shallow to deeper shelf waters.

In shallow lagoons adjacent to a low coast (zones VII and VIII), the terrigenous influx was very slight. The energy level was at its minimum and carbonate-mud sedimentation prevailed. The fossil assemblage is dominated by diverse foraminifers and algal structures and in places, thin-shelled productoids and rhynchonelloids with locally occurring lingulids. The unique nature of the assemblage with the bryozoans and most brachiopods absent from the environment indicates restrictive ecological conditions. This resulted probably from a variation in water salinity and/or temperature. The foraminifers *Ammovertella* and algae occur mostly in more marly sediments assigned here to extremely shallow, more onshore parts of the lagoons. The other foraminifers of this mega-association occur in limestones which may border directly upon bank deposits. In these cases, there is no terrigenous matter in the bank limestones but instead, pure micritic-limestone intercalations occur with a very sparse

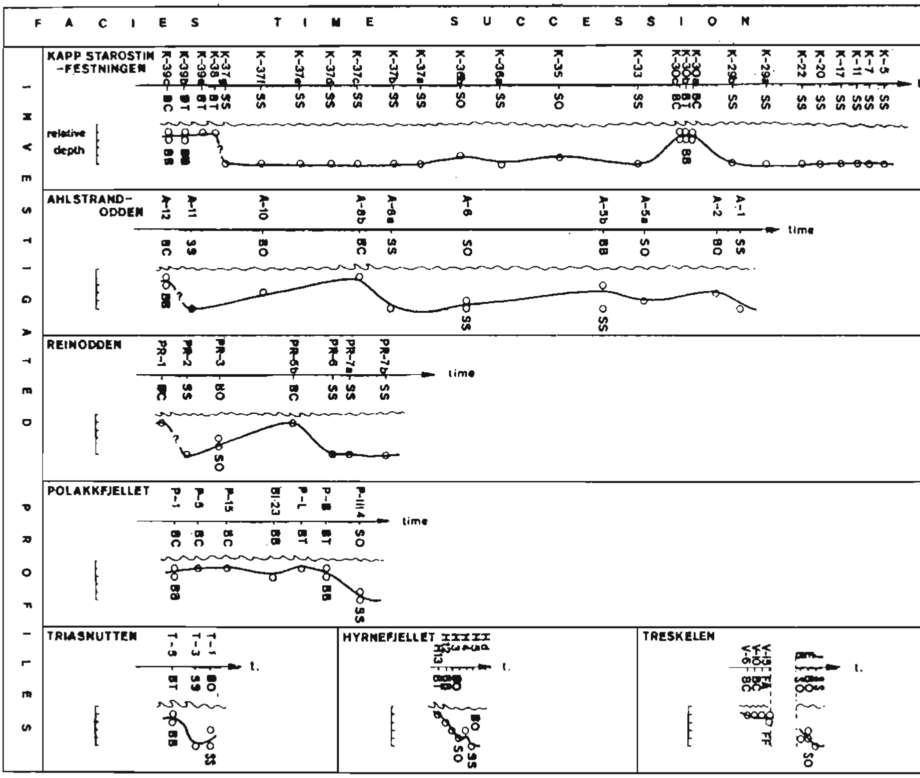


Fig. 4. Facies succession in particular sections. Marked are the samples and changes in relative depth in time. Sample symbols (e.g. K-20, P-III4) and facies symbols (e.g. SS, BT) are given, circles mark facies positions, the solid curve indicates changes in relative depth in time, the wave line mark sea level.

macrofauna. The density and diversity of fossils is lower in these sheltered carbonate environments than in their terrigenous counterparts.

The above-discussed facies model for the Kapp Starostin Formation can also be used to interpret the facies succession for the investigated sections (fig. 4). The inferred changes in relative water depth reflect probably some eustatic changes in the sea level. Then, those diagrams may make a great help in chronostratigraphic correlation among the sections.

REFERENCES

ALLEN, J. R. L. 1967. Depth indicators of clastic sequences. — *Marine Geology*, 5, 429—446.

BENZÉCRI, J. P. 1973. L'analyse des Données. 2. L'analyse des Correspondences. Dunod; Paris. 619 pp.

BENDICT, III, G. L. and WALKER, K. R. 1978. Paleobathymetric analysis in Paleozoic sequences and its geodynamic significance. — *Am. J. Sci.*, **278**, 579—607.

BIRKENMAJER, K. 1964. Devonian, Carboniferous and Permian Formations of Hornsund, Vestspitsbergen. — *Studia Geol. Polonica*, **11**, 47—123.

— and CZARNIECKI, S. 1960. Stratigraphy of marine Carboniferous and Permian deposits in Hornsund (Vestspitsbergen), based on brachiopods. — *Bull. Acad. Polon. Sci., Sér. sci. géol. géogr.*, **8**, 203—209.

— and LOGAN, A. 1969. On the fauna and age of the *Cancrinella* Limestone (Permian) at Kopernicusfjellet, Vestspitsbergen. — *Norsk Polarinst. Årbok 1967*, 28—45.

BUROV, YU. P., GAVRILOV, B. P., KLUBOV, B. A., PAVLOV, A. V., USTRITSKY, V. I. (БУРОВ, Ю. П., ГАВРИЛОВ, Б. П., КЛУБОВ, Б. А., ПАВЛОВ, А. В., УСТРИЦКИЙ, В. И.) 1965. Новые данные о верхнепермских отложениях Шпицбергена. Сборник: Материалы по геологии Шпицбергена. Изд. НИИГА.

CUTBILL, J. L. and CHALLINOR, A. 1965. Revision of the stratigraphical scheme for the Carboniferous and Permian rocks of Spitsbergen and Bjørnøya. — *Geol. Mag.*, **102** (5), 418—439.

FORBES, C. L., HARLAND, W. B., HUGHES, N. F. 1958. Paleontological evidence for the age of the Carboniferous and Permian rocks of Central Vestspitsbergen. — *Ibidem*, **95** (6), 463—490.

FREBOLD, H. 1937. Das Festungsprofil auf Spitsbergen. Die Brachiopoden und Lamellibranchiatenfauna und die Stratigraphie des Oberkarbons und Unterperms. — *Skr. Svalbard og Ishavet*, **69**, 9—94.

GOBBETT, D. J. 1963. Carboniferous and Permian Brachiopods of Svalbard. — *Norsk Polarinst. Skr.*, **127**, 7—201.

JOHNSON, R. G. 1960. Models and methods for analysis of the mode of formation of fossil assemblages. — *Bull. Geol. Soc. Amer.*, **71** (7), 1075—1085.

MAŁECKI, J. 1968. Permian Bryozoa from the Tokrössöya Beds, Sörkapp Land, Vestspitsbergen. — *Studia Geol. Polonica*, **21**, 7—31.

— 1977. Permian Bryozoans from Southern Spitsbergen and Bjørnøya (Svalbard.) — *Ibidem*, **60**, 73—88.

ORVIN, A. K. 1940. Outline of the Geological History of Spitsbergen. — *Skr. Svalbard og Ishavet*, **78**, 1—57.

PARK, R. A. 1968. Paleoecology of *Venericardia s. l.* (Pelecypoda) in the Atlantic and Gulf Provinces — An application of paleosynecological methods. — *J. Paleont.*, **42**, 955—986.

SARYTSCHEVA, T. G. (САРЫЧЕВА, Т. Г.) 1977. (ed.) Брахиоподы верхнего палеозоя Сибири и Арктики, Позднепалеозойские продуктиды Сибири и Арктики. — *Труды Пал. Инст. АН СССР*, **161**, 162.

SCHOPF, T. J. M. 1969. Paleoecology of ectoprocts (bryozoans). — *J. Paleont.*, **43** (2), 234—245.

SIEDLECKA, A. 1970. Investigations of Permian cherts and associated rocks in southern Spitsbergen. Part I and part II. — *Norsk Polarinst. Skr.*, **147**, 5—87.

SOSIPATROVA, G. P. (СОСИПАТРОВА, Г. П.) 1967. Верхнепалеозойские фораминиферы Шпицбергена. — Сборник: Материалы по стратиграфии Шпицбергена, 94—120, изд. НИИГА.

STIEPANOV, D. L. (СТЕПАНОВ, Д. Л.) 1957. О новым ярусе пермской системы в Арктике. — *Вестн. ЛГУ, сер. геол. и геогр.*, **24**, вып. 4, 20—24.

— 1973. The Permian System in USSR. — *In*: The Permian Triassic systems and their mutual boundary. Ed. A. Logan and L. V. Hills, 120—136.

SZANIAWSKI, H. and MAŁKOWSKI, K. 1978. Conodonts from the Kapp Starostin Formation (Permian) of Spitsbergen. — *Acta Palaeont. Polonica*, **24, 2, 231—264.**

USTRITSKY, V. I. (УСТРИЦКИЙ, В. И.) 1967. Основные черты стратиграфии и палеогеографии верхнего палеозоя Шпицбергена. — Сборник· Материалы по стратиграфии Шпицбергена, 71—93, изд. НИИГА.

— 1971. Биостратиграфия верхнего палеозоя Арктики. — *Труды НИИГА*, **164**, 4—263, изд. НЕДРА.

WINSENES, T. S. 1966. Observations on the Carboniferous and Permian rocks of Vestspitsbergen. — *Norsk Polarinst. Årbok 1964*, 7—29.

KRZYSZTOF MAŁKOWSKI i ANTONI HOFFMAN

MODEL FACJALNY DLA OSADÓW PERMSKIEJ FORMACJI KAPP STAROSTIN, SPITSBERGEN

Streszczenie

Utwory permskie odsłaniające się na terenie Zachodniego Spitsbergenu (fig. 1), zaliczane do formacji Kapp Starostin, opróbowano litologicznie w siedmiu profilach (fig. 2). Wykonano badania mikrofacjalne dwustu płytek cienkich wykonanych z pobranych prób. Przy użyciu komputera CYBER przeprowadzono pół-ilościową analizę czynnikową biotycznych i abiotycznych składników facji (tab. 1, 2). Na podstawie otrzymanych z tej analizy wydzieleń (tab. 1, pls 2, 3), oraz interpretacji faktów, zaobserwowanych w szlifach i odsłonięciach, skonstruowano facjalny model (fig. 3). Model ten może służyć przy rekonstrukcji przestrzennej zbiornika lub odtworzeniu jego facjalnego rozwoju w czasie (fig. 4).

EXPLANATIONS TO THE PLATES 2 AND 3

Plate 2

Examples of microfacies corresponding to computed facies divisions:

1. Sample P-L, facies symbol BT.
2. Sample A-5b, facies symbol BB.
3. Sample K-39c, facies symbol BC.
4. Sample H-3, facies symbol BO.

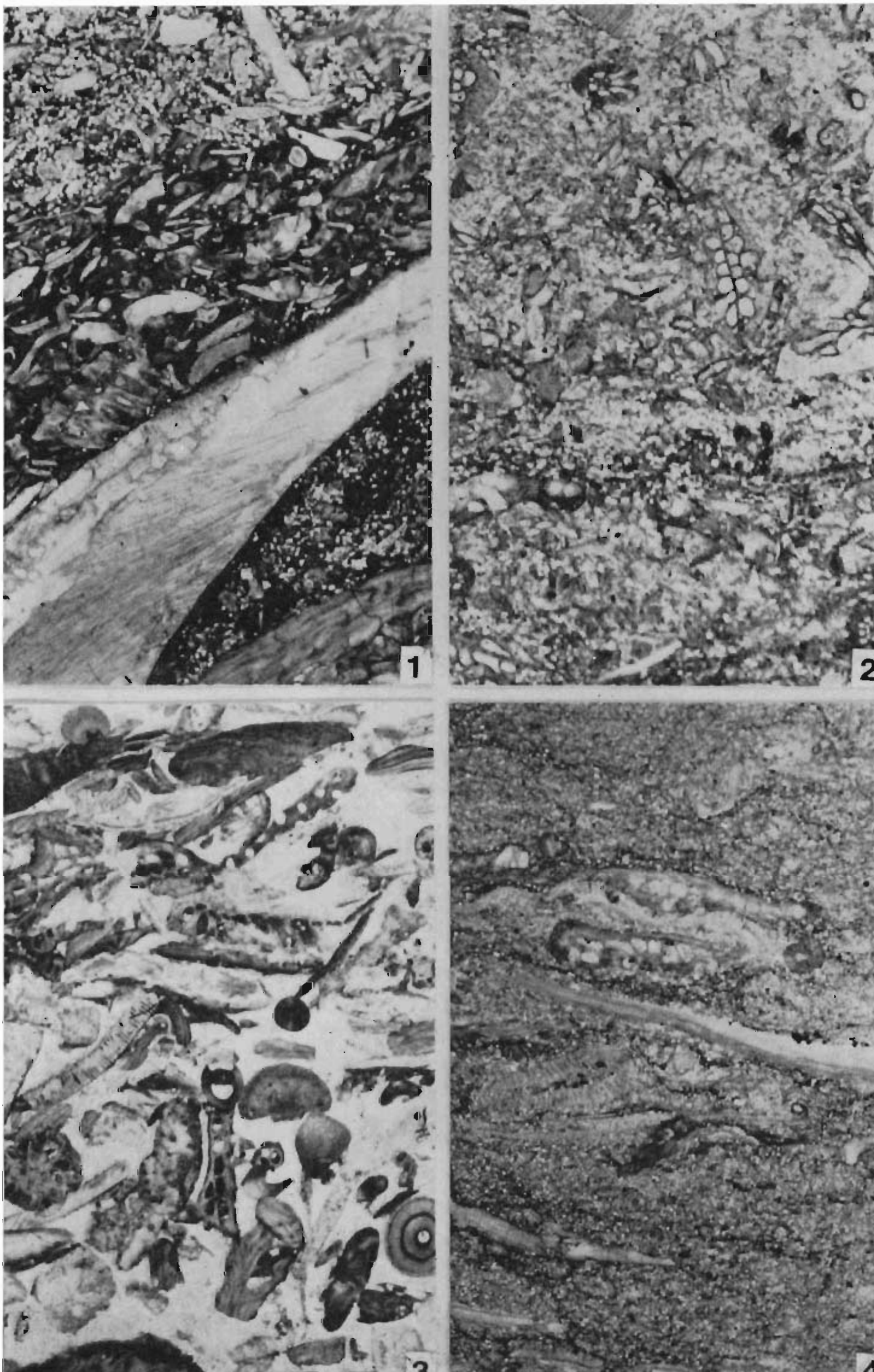
Photo: E. Wyrzykowska

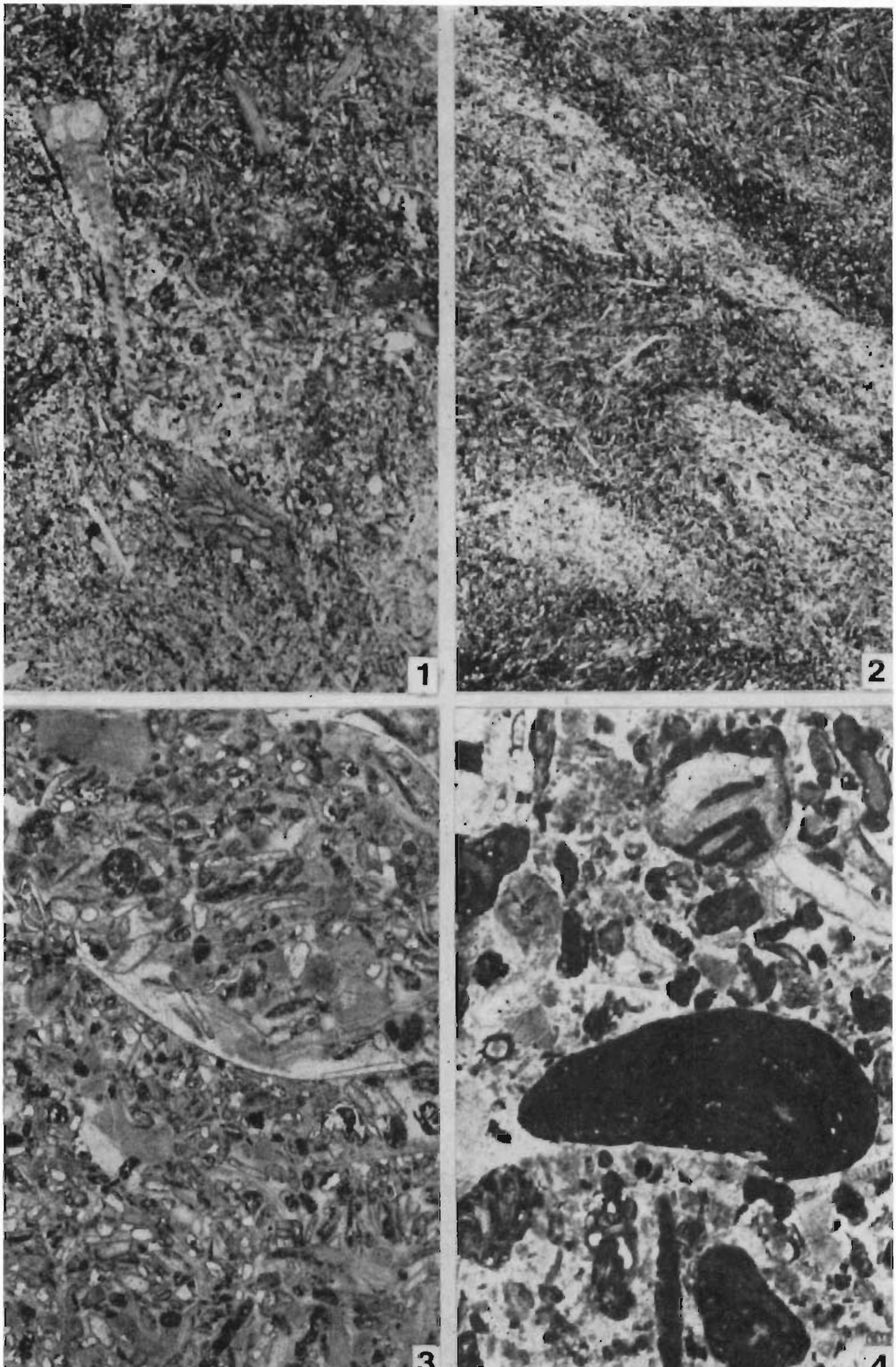
Plate 3

Examples of microfacies corresponding to computed facies divisions:

1. Sample A-5a, facies symbol SO.
2. Sample K-33, facies symbol SS.
3. Sample P-2, facies symbol FF.
4. Sample V-15, facies symbol FA.

Photo: E. Wyrzykowska


1
2
3
4


1
2
3
4