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DEDICATION

ROMAN KOZŁOWSKI
(1889–1977)

The present volume is dedicated to the late Professor Kozłowski, eminent Polish palaeontologist, one of the contemporary leaders in the field of graptolite studies.

Roman Kozłowski was born on February 1, 1889, in Włocławek, northwest of Warsaw, into the family of a forester. In 1905 he actively participated in a school strike against the ban on teaching in Polish in the part of Poland which was then under administration of tsarist Russia. Two years later he finished school at Włocławek and, at the age of 18, left Poland for Switzerland where he took up natural sciences at the University of Fribourg for one year. Then he moved to Paris to continue his studies in the Sorbonne. He graduated from the Sorbonne in 1910 with the degree of licentiate in natural sciences. Between 1910 and 1913 he conducted palaeontological investigations under Marcellin Boule at the Museum of Natural History in Paris. In 1913 he accepted an invitation to work at the National School of Mines at Oruro (Escuela National de Minas de Oruro), Bolivia. He went there with his wife, a botanist, who had also graduated from the Sorbonne. In 1916 the Bolivian government offered him the post of Director of the school with the task of reorganizing it into the National School of Mining Engineers (Escuela National de Ingenieros de Minas de Oruro). Between 1916 and 1919 he was both Professor and Director of the school. The years from 1919 to 1921 saw him travelling in the Bolivian Andes with the aim of collecting palaeontological and mineralogical materials. Later his collections formed the core of his own investigations and those of other Polish scientists.

In 1921, after his eight-year stay in Bolivia, Kozłowski returned to Poland in response to the call of the Polish government. But before taking up teaching at Warsaw University he once again went to Paris in order to complete his doctoral thesis. During the next two years in Paris (1921—1923) he continued investigations on the Devonian invertebrates he had collected in the Andes.

In 1923, upon receiving the degree of Doctor of Natural Sciences from the Sorbonne, he finally came back to Poland to remain there for the rest of his life. But times were hard and financial difficulties did not permit Warsaw University to establish a Chair of Palaeontology as it had been planned earlier. Instead, in 1924 Kozłowski assumed the Chair of Palaeontology and Geology at what would today be known as the Polish Open University, being also a part-time lecturer of palaeontology at Warsaw University. Finally, in 1927, the Chair of Palaeontology was established at Warsaw University where Kozłowski became Full Professor.

One of the first Nazi bombs dropped on Warsaw in September 1939 hit the Palaeontology Department of the University. The Department, which had been Professor Kozłowski's creation, burnt down destroying in the flames the rich palaeontological collections and the library.

During the years of occupation (1940—1945) Kozłowski worked as curator of geological collections at the Polish Geological Institute, which at the critical period of Nazi rule could not operate under its original name. Nevertheless, the Institute offered possibilities of certain scientific research to quite a few Polish geologists and was also a centre of an active underground movement.

From the rubble and ruins of the Second World War Kozłowski rebuilt the Warsaw University Department of Palaeontology. Later, in 1952, he founded the Institute of Palaeozoology (now of Palaeobiology) of the Polish Academy of Sciences. Both institutions have always occupied the same premises, Professor Kozłowski being the head of the two until he retired in 1960. For him these institutions formed an indivisible whole. From 1960 to 1974 the retired Professor hardly missed a day in coming to the laboratory and continuing his research.

In the post-war years Kozłowski's was a great contribution to the organizing and revitalizing of Polish science. He was a member of the Secondary School Programme Commission at the Ministry of Education. There was a special Commission on the Reviving of Polish Science at the Central Planning Office of which Kozłowski was Vice-Chairman from 1946 to 1949, while between 1948 and 1952 he participated in the Commission on the Organization of Polish Science at the Main Council of the Ministry of Education. He was also a member of other important Councils and Boards. In 1951 he was elected a full member of the Polish Academy of Sciences and as such took an active part in the work of the Academy. From 1954 to 1968 he was a member of the Praesidium of the Academy.

Professor Kozłowski died on May 2, 1977, at the age of 88, in Warsaw.

During his stay in Bolivia Kozłowski published several papers on that country's geology and mineral resources. From Oruro, a centre of unique silver and tin ore-bearing deposits, he visited mining areas and vast regions of the Bolivian Andes which had been inadequately explored. He conducted comprehensive geological field observations and accumul-

ated rich collections of rocks and minerals. Kozłowski anticipated that, on his return to Europe, he would find the opportunity for laboratory investigation of those materials and for publishing the results.

He carried out some of these plans during his next two years in Paris, where he chiefly concentrated his efforts on his doctoral thesis in the field of palaeontology. Kozłowski also made time to work at the Mineralogical Laboratory of the National Museum of Natural History under the famous mineralogist, Professor A. Lacroix. When he returned to Poland, Kozłowski decided to lend his Bolivian mineralogical collections to his Polish colleagues for investigation.

But palaeontology had always been his main passion in life. And it was his study in this field that brought him world renown. Among his thirty six published works in palaeontology, four are extensive fundamental monographs, the result of many years of study.

One can differentiate two periods in Kozłowski's palaeontological research. The first of these, from 1910 to 1929, was chiefly concerned with investigations on Palaeozoic brachiopods. Three fundamental monographs stand out among his works on this subject, namely: "Les Brachiopodes du Carbonifère supérieure de Bolivie" ("Annales de Paléontologie, IX, 100 pp., Paris 1914), his doctoral thesis "Faune dévonienne de Bolivie" ("Annales de Paléontologie", XII, 112 pp., Paris 1923) and his monograph on the Silurian brachiopods of Podolia entitled "Les Brachiopodes gothlandiens de la Podolie polonaise" ("Palaeontologia Polonica", I, pp., 254 Warszawa, 1927) which he wrote on his return to Poland.

What makes these works so attractive is not only the author's comprehensive approach to the palaeontological material and the problems under study but also the diverse techniques he used to achieve his aim. Kozłowski had a talent for introducing new methods into investigations of fossil material thus making his analysis more precise and profound. For instance, he employed the method of serial grinding of closed valves in order to study the interior structure of fossil brachiopods. This permitted him to reconstruct the inside of a skeleton which would be otherwise almost inaccessible. He also studied the microstructure of the valves in thin sections, used thermal shocks to separate the valve from the kernel and, finally, in the case of a favourable secondary mineralization, he applied etching as a method of isolation. Introduction of these new and diverse techniques together with studies on variability and ontogeny opened new prospects in the research of fossil brachiopods. For many years Kozłowski's works have been quoted in papers concerning Palaeozoic brachiopods providing a model of scientific work to young palaeontologists.

A new chapter in Kozłowski's research was opened in 1930, following the discovery of the unusually well-preserved remains of graptolites in the Lower Ordovician deposits of the Holy Cross Mountains (in the locality

of Wysoczki). Kozłowski etched these remains with hydrofluoric acid which dissolved the chalcedony rock without attacking the organic material of graptolite skeletons.

Many years of systematic work enabled him to accumulate abundant materials embracing organic skeletons of graptolites and other animal groups which were later subjected to careful investigation with the best contemporary techniques. Among Kozłowski's most important innovations one should mention a wide-scale application of histological methods. After etching, the graptolite remains were embedded in paraffin in much the same way as tissue preparations of recent animals — to be further sectioned with a microtome and studied for details of their microscopic structure. As a result of these studies Kozłowski recognized two basic tissues in a graptolite skeleton, namely: the fusellar tissue and the cortical one. Use of the same technique enabled him to discover that budding in graptolites is due to a stolon, i.e. a cord of soft tissues connecting individual zooids. The discovery of the stolon of which nothing but a pellicle can be observed in the fossil state, made it possible not only to associate that structure with the budding but also to trace its regular nature in graptolites of different orders. Thus, in Dendroidea the zooids bud to form triads, while in other orders the new individuals appear in diads. The material from Wysoczki was also used to suggest a biological interpretation of the astogeny, or development of a colony from the formation of the larval skeleton, through its metamorphosis into the first zooid of the colony to the budding of the remaining zooids.

A profound knowledge of the details of fossil graptolites structure and development convinced Kozłowski that it would be wrong to ascribe them all to Dendroidea as they form a much greater variety of orders. He distinguished such new orders as Tuboidea, Camaroidea, Stolonoidea and later, in 1962, Crustoidea. Kozłowski's studies also shed a new light on the systematic position of graptolites. At the time it was still very vague, in spite of graptolites being studied for years as one of the most abundant and important groups of index fossils. Some authors referred graptolites to coelenterates, the others, in turn, to bryozoans. Professor Kozłowski proved that they showed no close relationship to either of them. But his studies revealed an unusual similarity between the fossil graptolites and the recent colonial marine invertebrates known as Pterobranchia. The latter belong to Hemichordata and strikingly resemble graptolites in that their skeleton is made up of unique spindle-like bands (fuselli) unknown in any other animal group. The presence of a stolon inside the skeleton, together with the manner of budding of the first zooid in the colony is another feature making Recent pterobranchs and fossil graptolites so strikingly alike. Both groups must have had a common ancestry, with their phylogenetic lineages having diverged at the beginning of the Cambrian. According to Kozłowski, graptolites and

pterobranchs form separate classes of the hemichordate phylum. He also believed that pterobranchs could be taken for the ancestors of graptolites. The main conclusions as to the graptolite structure, development and systematic position were first formulated in Kozłowski's preliminary report published in 1938. His basic extensive monograph "Les Graptolites et quelques nouvaux groupes d'animaux du Tremadoc de la Pologne" did not come out until 1949, though the manuscript had been completed ten years earlier. The outbreak of the war and the tragic events that followed, forced a long interruption in his work.

The fate of Kozłowski's manuscript provides us with a quite dramatic and even heart-rending story. When the Nazis began to bomb Warsaw in 1939, he found a hiding place for the manuscript and specimens embedded in glycerine in the basement of Warsaw Seismological Observatory. His microtome sections were lost a few days later in the destroyed building of the Department of Palaeontology. Kozłowski had no access to the basement where the manuscript had been hidden for over a month, since after the battles were over the German troops occupied the Observatory. When Kozłowski finally entered the basement he found the place plundered, with no trace of his materials. By a stroke of luck he recovered part of his original manuscript and all his specimens scattered among the University ruins a few months later while his friend Professor W. Roszkowski rescued the rest of it from a pile of snow in a courtyard.

In August, 1944, during the Warsaw uprising, Kozłowski was forced to leave the city like hundreds of thousands of his compatriots. Before leaving, he hid his manuscript once again, this time in the central heating pipes of his house. In 1945 the house was lying in ruins, but Kozłowski managed to find the manuscript undamaged in its "shelter". As the negatives of his plates happened to survive in Paris where Kozłowski had sent them before the war, he finally was able to publish the full text with illustrations in 1949.

One cannot overestimate the importance of this monograph, a major achievement of XX century palaeontology. Its significance reaches far beyond the scope of graptolite studies, being a model of a new, advanced approach to fossil material. It involves the use of modern techniques in palaeontological investigations which brings closer the methods employed for the study of fossils and of living animals. This approach also makes it possible to closely associate the fossil group under study with the similar recent one and thus to make wider generalizations.

It is only natural that Kozłowski's concepts were soon recognized by the leading specialists in both palaeontology and zoology. Particularly important among palaeontologists was the opinion of Professor O.M.B. Bulman, the famous English scholar. As early as 1938 he highly appraised Kozłowski's research on the strength of his preliminary report, and later used his fundamental monograph as the basis for a biological interpreta-

tion of the graptolite colony and for establishing this group's systematic position. The classical palaeontological and zoological textbooks fully accepted Professor Kozłowski's viewpoint. The zoological views were greatly influenced by V.N. Beklemishev, an outstanding Russian zoologist and comparative anatomist who, after some modifications, corroborated Kozłowski's conclusions.

Professor Kozłowski's arguments in his 1949 monograph were strengthened by his further remarkable discoveries. Mention is due to the discovery of the pterobranch fossil remains in Palaeocene, Cretaceous (1946, 1956) and, finally, Ordovician deposits (1961, 1967, 1970). This shattered the objections of some authors that Kozłowski derived graptolites, an ancient fossil group, from the geologically much younger, exclusively Recent pterobranchs. He also revealed a remarkable similarity in the early stages of development between the tuboid graptolite colonies and the embryonic vesicle of pterobranchs (*Rhabdopleura*).

All these discoveries confirmed the conviction that there was a close affinity between graptolites and pterobranchs. There was some criticism, however. In 1950 the Swedish palaeontologist B. Bohlin expressed his doubts concerning the model of secretion of graptolite skeleton as interpreted by Kozłowski and suggested that this group should be referred to the phylum of coelenterates. Later Ch. E. Decker, an American palaeontologist, presented his considerations along the same lines. L. H. M. Hyman, another American zoologist, in her text-book published in 1951, also tried to shake Kozłowski's arguments by pointing out the following: unlike graptolites whose rhabdosome was believed to be chitinous, pterobranchs had their skeleton made of protein. Kozłowski did not reply to these objections until 1966. In his article, which appeared in the Journal of Palaeontology, we note among other arguments, a reference to the investigations of M. F. Fucart, a Belgian biochemist who found numerous aminoacids in the skeletons of both Recent Pterobranchia and fossil graptolites. The objections to Kozłowski's views often resulted from misunderstandings and errors due to insufficient knowledge of either the fossil or living material. They could hardly provide a foundation for an opposite hypothesis which would rival Kozłowski's interpretation in the richness of its evidence and in the elegance of its reasoning.

Therefore, the original intention of the first ultrastructural studies of the graptolite skeleton was to find further proofs of the classical theory using newly advanced techniques. The results, however, were quite unexpected; they brought new complications to the problem which seemed to have been solved. The joint investigations of A. Urbanek and K. M. Towe published between 1972 and 1975 showed that the graptolite skeleton is made of an entirely different material than that in *Rhabdopleura*. The differences are essential, suggesting that colagen and keratin were the major skeleton-building fabrics in graptolites and *Rhabdopleura*

respectively. Further studies revealed that the pattern of rhabdopleuran skeleton ultrastructure had been remarkably specific throughout the history of the group so that the Ordovician pterobranchs varied as distinctly from graptolites as does the Recent *Rhabdopleura*.

Upon considering the entirety of the ultrastructural data Urbanek came to the conclusion (1976) that Professor Kozłowski's model of skeleton secretion may be wrong. That model implied that the fusellar tissue could be produced in exactly the same way in both groups; whereas the cortical layer, unique for graptolites, appeared due to a specialized secretional organ, namely a tissue membrane (referred to as the extrathecal membrane). Each layer of the skeleton, thus, would be secreted by a different part of the graptolite body, forming a dualistic model of secretion. The ultrastructural studies, in turn, suggested the hypothesis of a uniform mode of secretion, that is, that all layers of the skeleton are produced by the same part of the zooid body. In postulating this Urbanek believes that both tissues were secreted by the perithecal membrane, inside the folds of the secretional tissue, in other words, in a manner completely different from that of pterobranchs. These basic differences in the fabric and in the mode of skeleton formation eliminate, in Urbanek's opinion, the possibility of graptolites and pterobranchs being closely related. His view is shared neither by D. Andres, nor by P. Crowther and R. B. Rickards. In their papers published in 1976—1977, they stress that many graptolites display their cortical tissue in the shape of narrow bandages randomly applied onto the surface of the skeleton. They also regard the mode of secretion as uniform, but, unlike Urbanek, believe it to be of the pterobranch type. This means that the cortical tissue would be secreted by a special cephalic disc acting like a painting brush due to the ability of the zooid to creep over the skeleton surface. Such an approach, though discarding the dualistic model of secretion suggested by Professor Kozłowski, permits the concept of a close graptolite — pterobranch affinity to be preserved.

Regardless of where the odds will be in this dispute, it is thanks to Professor Kozłowski's investigations that the origin and systematic position of graptolites remain a most fascinating problem, among many others he was the first to introduce into palaeontology.

In the post-war period Kozłowski developed wide-ranging research in the Institutes of Warsaw University and the Polish Academy of Sciences, one of which, as we know, was rebuilt and the other founded due to his efforts. A great emphasis was placed upon etching fossil organisms with organic or phosphatic skeletons from sedimentary rocks (chiefly Palaeozoic limestones from bore cores and erratic boulders). And this process in which many tons of limestone were dissolved continued for about thirty years. This work bore fruit: the Ordovician and Silurian deposits yielded numerous marine invertebrates with organic skeletons

which up to then had been either quite unknown or inadequately investigated. Some of these materials were studied by Kozłowski personally, some — by his students. As one of his most important findings we should mention rare fossil Hydrozoa with a chitinous skeleton that Kozłowski etched from the Ordovician limestones. He was also one of the first to discover complete fossil jaw apparatus of polychaetes, radiolarians, hystrichosphaerids, conularians, bryozoans and numerous other marine invertebrates. The innovative techniques he introduced into palaeontology, the etching of specimens from the rock and embedding them in glycerine in particular, gradually won out, being now widely accepted by various centres doing research of fossil invertebrates throughout the world.

As far as the graptolite studies are concerned, in the postwar period Kozłowski did a lot to produce more original data and to increase the knowledge of morphology, taxonomy and evolution of several groups. Extremely important was his work concerning *Dinemagraptus* (1951). This remarkable graptolite having a dichograptid foundation displays a strong peridermal reduction. Other contributions of Kozłowski include his studies on *Corynoides* and the related forms (1953, 1956) as well as the paper concerning some Dichograptidae which provided new information upon thecal morphology in *Didymograptus, Holmograptus* and also upon lateral branching of Dichograptidae. Professor Kozłowski also described the unusual genus *Pararygograptus* that exhibited a unique reduction of rhabdosome as expressed in preserving the left, not the right branch, which is the case in *Azygograptus*.

His further research yielded information on *Calyxdendrum* (1960), a mozaic form with a graptolite sicula but a dendroid pattern of thecal budding, as well as on aberrant *Graptolodendrum* (1966) also combining some traits of both orders. But of special interest was the discovery and description of morphology of a new order of sessile graptolites — Crustoidea (1962). Still later Kozłowski enriched our knowledge of graptolites by describing a specific structure which can be observed in some Ordovician Tuboidea and Dendroidea and which he called "tubotheca" (1970). His last work dealt with the early stage of development and mode of life of graptolites; it contained new data about Tuboidea together with an attempt at a biological interpretation of reproduction and ecology of sessile and free-living graptolites.

A great deal of Kozłowski's time and attention was given to editorial work. In 1929 he founded the series of monographs "Palaeontologia Polonica", and in 1956, a quarterly "Acta Palaeontologica Polonica". He was a most devoted editor of both of them for many years.

Roman Kozłowski was also an outstanding teacher. He not only fascinated his students with the style and precision of his lectures, he was also an understanding though demanding supervisor for the young scientists

doing their doctoral research. He founded the Polish school of palaeontology having educated among his students and followers both experts in almost all groups of fossil organisms to be found in Poland, and specialists who are doing wide-scale research outside the country. He derived greater satisfaction from the success of his students than from his own and knew how to create around him an atmosphere of friendliness and cooperation so important in scientific effort.

His work brought Kozłowski world fame and recognition. He was given the title of Doctor Honoris Causa by the Universities of Cracow, Paris and Modena, he was an honorary member of the French, Czechoslovak and Colombian Academies of Sciences and of many Polish and foreign scientific societies. The US Academy of Sciences awarded him a gold medal; he also received a silver medal from the Czechoslovak Academy of Sciences and the Geological Societies of Belgium and London. He was a Polish Scientific Prize-winner of the first order. On him were conferred the following honours: the Commodore's Cross of the "Polonia Restituta", the Order of the Labour Banner of the first and second class and also the Medal of the Tenth Anniversary of People's Poland, the Tenth Anniversary Medal of Warsaw University and the Copernicus Medal.

To the wide circle of his students and co-workers, Professor Kozłowski was not only a great scientific but also a great moral authority. His whole life was an example of honest decent living; he taught us how to choose the straight road, how to avoid human conflicts, but at the same time how to be consistent and unbending in the pursuit of the right cause, in the fight for justice, for the good fame and high standards of Polish science.

In everything he did, Professor Kozłowski strove for perfection. Indifferent to titles and honours, he was an extremely kind and modest man, which made this great scientist an almost legendary figure for the present generation of naturalists.

Zofia Kielan-Jaworowska
Adam Urbanek

SCIENTIFIC LEGACY OF PROFESSOR ROMAN KOZŁOWSKI

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3. La Salvadora. Contributión al estudio de los yacinientos metalíferos de Bolivia. 23 pp., La Paz 1916.
4. Note préliminaire sur les gisements d'étain et d'argent de Bolivie (*Bull. Soc. franc. Mineral.*, **44**, 24 pp., 1919).

5. Apuntes acerca de unviaje geológico por los departamentos de la Paz Potosi y Chuquisaca (*Bol. Soc. Geograf.*, **28**, 56 pp., La Paz 1920).
6. Faune dévonienne de Bolivie (*An. Paleont.*, **12**, 112 pp., 1923).
7. A propos de l'âge du soulevement de la Cordillière de Bolivie (*Bull. Soc. Géol. France*, **23**, 5 pp., 1923).
8. Sur le Dévonien au Pérou (*C. R. Soc. Géol.* France, 2 pp., 1924).
9. Sur certains Orthidés ordoviciens des environs de St. Petersburg (*Bibl. Univ. Liberae Polonae*, **17**, 21 pp., Warszawa, 1927).
10. Les Brachiopodes gothlandiens de la Podolie polonaise (*Palaeont. Pol.*, **1**, 254 pp., 1927.
11. *Andobolus* gen. nov. et quelques autres Brachiopodes Inarticulés de l'Ordovicien de Bolivie (*Serv. Géol. Pol.* **6**, 21 pp., Warszawa 1930).
12. Phosphorites dans le Cambrien de Sandomierz (*Ibidem*, 6, 5 pp., 1931).
13. (and S. Jaskólski) Les gisements argento-stannifères d'Oruroyen Bolivie. (*Ibidem*, **8**, 100 pp., 1932).
14. Skały magmowe Andów Boliwijskich (*Ibidem*, **10**, 8 pp., 1934).
15. Esquisse de la répartition des roches éruptives dans les Andes de Bolivie (*Ibidem*, **10**, 39 pp., 1935).
16. (with S. Jaskólski) Les gisements argento-stannifères de Chocaya en Bolivie. Aperçu géologique (*Ibidem*, **11**, 9 pp., 1935).
17. Information préliminaires sur les Graptolithes du Tremadoc de la Pologne et sur leur portée théorique (*An. Mus. Zool. Pol.*, **13**, 12 pp., 1938).
18. Les affinités des Graptolithes (*Biol. Rev.*, **22**, 16 pp., 1947).
19. Découverte du Ptérobranche *Rhabdopleura* à l'état fossile dans le Crétacé supérieur en Pologne (*C. R. Ac.*, 3 pp., 1949).
20. Les Graptolithes et quelques nouveaux groupes d'animaux du Tremadoc de la Pologne (*Palaeont. Pol.*, **3**, 235 pp., 1948/1949).
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22. Etude d'une nouvelle espèce du genre *Corynoides* (*Ibidem*, **3**, 14 pp., 1953).
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24. Sur *Rhabdopleura* du Danien de Pologne (*Acta Palaeont. Pol.*, **1**, 1, 21 pp., 1956).
25. Sur quelques appareils masticateurs des Annelides Polychetes ordoviciens (*Ibidem*, **1**, 3, 46 pp., 1956).
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27. (with P. Greguss) Discovery of Ordovician Land Plants (*Ibidem*, **4**, 1, 10 pp., 1959).
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29. Un microfossile énigmatique (*Ibidem*, **4**, 3, 5 pp., 1959).
30. *Calyxdendrum graptoloides* n.gen., n.sp., (*Ibidem*, **5**, 2, 20 pp., 1960).
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32. Crustoidea — nouveau groupe de Graptolithes (*Ibidem*, **7**, 1—2, 50 pp., 1960).
33. Le dévelopment d'un Graptolithe tuboïde (*Ibidem*, **8**, 2, 32 pp., 1963).
34. Sur la nature des Chitinozoaires (*Ibidem*, **8**, 4, 25 pp., 1963).
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36. On the structure and relationships of Graptolites (*J. Paleont.*, **40**, 3, 1966).
37. *Graptolodendrum mutabile* n.gen., n.sp. — an aberrant dendroid graptolite (*Acta Palaeont. Pol.*, **11**, 1, 12 pp., 1966).
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39. (with J. Kaźmierczak) On two Ordovician calcareous Algae (*Ibidem*, **3**, 22 pp., 1968).
40. Nouvelles observations sur les Conulaires (*Ibidem*, **13**, 4, 35 pp., 1968).

41. Nouvelles observations sur les Rhabdopleurides (Pterobranches) Ordoviciens (*Ibidem*, **15**, 1, 12 pp., 1970).
42. Tubotheca — a peculiar morphological element in some Graptolites (*Ibidem*, **15**, 4, 18 pp., 1970).
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