

Academician Milan Herak's Main Contribution to Palaeontology

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The main contribution of Herak's palaeontological research carried out over a long period of time, began during his early career in the Geological-Palaeontological Museum in Zagreb between 1943 and 1952. Therefore his first publications concerned the field of palaeontology. Within that scientific discipline Herak made a significant contribution to the analysis of Triassic calcareous sponges from the "Sycones" group (HERAK, 1943, 1944). He investigated and presented the morphological "characters" of five genera, and particularly those species where, on newly discovered material, he recognized some new features. He also established a new genus and species *Oligoplagia carnica*. All previously known forms and their distribution were the subject of this Herak's paper with special emphasis on the vertical distribution and lithogenesis of the group. From a lithogenetic point, Herak highlights the genus *Amblysiphonella*, as well as the genera *Oligoplagia* and *Holo-coelia*. Herak also drew palaeoecological conclusions regarding the isolation of their habitat. He was only able to attribute stratigraphic value to two species: *Colospongia dubia* (Upper Ladinian) and *Amblysiphonella timorica* (Middle Triassic).

One of the most significant "nonalgal" papers of professor Herak deals with the palaeontology of the cave bear (*Ursus spelaeus*) and although published in 1947, remains undoubtedly valid. It is obvious that this work has been stimulated by the rich Museum collection consisting of cranial vertebrae, long bones and teeth. This abundant osteological material was collected at various sites in Croatia (Medveda Cave near Lokve, Vindija, Bednik near Petrinja, Bobota, Vrapče, Cervačke Caves and others). In his study HERAK (1947) used biometric analysis and described morphological features of teeth, comparing his results with variational curve of the total range of the species (EHRENBURG, 1935). This work represents a significant contribution to the previous understanding of the most frequent Pleistocene animal remains in the Dinaric and circum-Dinaric karst region.

The greatest number of Herak's palaeontological works are related to the research of calcareous algae from Late Palaeozoic and particularly from the Triassic. This research has continued with variable intensity for over twenty years and resulted in Herak's numerous publications.

After a relatively long "silent period" of research on the calcareous algae of shallow-water carbonates during World War II and afterwards, Herak started a new chapter in the research of the calcareous algae, particularly the Dasycladaceae. Herak investigated various deposits from Croatia as well as from the former Yugoslavia, and thus he was among the first ones, together with Kochansky-Devidé, who initiated a new period of research on fossil algae in Europe. They were later accompanied by a number of authors from Zagreb where this kind of research has been traditional for more than a century. How is Herak's interest in the calcareous algae explained? Was it caused by the earlier discovery of, and research on the Upper Palaeozoic and adjacent Triassic in Mt. Velebit, done in the Salopek's team, or Herak's personal contact with Pia's works and algal material during his stay in Vienna? Was it because our scientists are predisposed towards the Triassic deposits or because of the idea that advancement in exploration of the Triassic is possible by detailed study of the calcareous algae, especially the Dasycladaceae? The last question reflects on the whole algae research of Herak which can be observed from two points of view: 1) taxonomic contributions and palaeontological consideration of separate genera and species and 2) the stratigraphic, i.e. biostratigraphic aspects. This is related to the vertical range of a specific taxon, or the complete algal association as well as their significance in the stratigraphic attribution of certain sediments or the recognition of contemporaneous facies.

In his first paper concerning the calcareous algae he wrote about their stratigraphic and palaeontological significance and stated some morphological characteristics (HERAK, 1950). He also surveyed particular elements

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of their phylogeny and pointed out the recapitulation of some ontogenetic stages which are probably analogous to phylogenetic stages. Herak viewed at the fossil finds on the basis of their distribution, and characteristics of the recent dasycladacean environment which can be taken as facies and climatic indicators, showing their lithogenetic importance in the development of the carbonate deposits. He highlighted the elements of algal structure which should be observed, and explained their importance for reliable determination, bearing in mind which characteristics are essential and which ones could be the consequence of adaptation. Herak indicted the relationship between the scientific diagnosis of the species and the number of researched i.e. observed samples, and the state of the original material which was used for primary description and reconstruction. Thus almost all the basic questions concerning calcareous algal research have been asked and they remain relevant today, so that Herak's work functions as the notification of the working hypothesis which will be realised in subsequent works. In this context Herak considers the genus *Diplopora* in the association of Triassic algae, which contains forms with a metaspondillous pattern of branches, while the other characteristics vary from species to species (HERAK, 1950). Herak treated the genus *Diplopora* and the relationship between their particular species several times, adding new observations and understanding of their stratigraphic position and significance (HERAK, 1950, 1956, 1957b, 1960, 1965). In these publications the distinction of the species *Diplopora annulatissima* and *D. annulata* with differentiated taxonomic criteria was realised. Frequent discoveries of the species *D. annulatissima* have been made at numerous sites in Croatia, particularly in Lika, in an association which is characteristic for the Ladinian (*D. annulata*, *Teutloporella herculea* etc.). Herak expanded the time span for this species to the Ladinian, thus extending the distribution of that species from a previous known Anisian age, documented in the Eastern and Southern Alps. Outside Croatia Herak's achievement was later used in various stratigraphic interpretations of the transitional zone between the "Mendola" dolomite to Buchenstein deposits in the range of the Sarl dolomite in the Southern Alps, as well as the time span for Anisian and Ladinian equivalents in the Silesian Triassic. Also, it was emphasized that part of the Wetterstein deposits belong to the Upper Ladinian, corresponding to several sites in Mt. Velebit.

In a more extensive analysis HERAK (1957b) discussed the problem of the species *D. annulata* which, according to Pia included three varieties (*dolomitica*, *septentrionalis* and *debilis*) and two forms of trichofora and vesiculifera which he considered to be the result of sexual dimorphism. Refuting all three varieties founded on unproved hypothesis as well as the sexual dimorphism, Herak relied on firm morphological distinctions of the species, and offered a new division of the species *D. annulata* into two subspecies. In one subspecies he included specimens with vesiculiferous branches and

according to the priority principle he nominated it as *D. annulata* subsp. *dolomitica* PIA and the second subspecies included specimens with trichoform branches as a type species nominated as *D. annulata* subsp. *annulata* HERAK. He established the time span for both subspecies up to the Upper Ladinian and this has been later well documented at numerous sites in the Dinarides.

HERAK (1965) extended his work on a detailed survey of the sites and morphological characteristics of several genera: *Teutloporella*, *Macroporella*, *Gyroporella*, *Oligoporella*, *Physoporella* and *Diplopora* and this enabled the elucidation of their basic morphological features and allowed determination of the relative stratigraphic positions as well as associations where the above taxa have been discovered. As in the case of *D. annulata* Herak preferred intraspecific category transferring the species *D. hexaster* and *D. helvetica*, into the subspecies *D. hexaster* subsp. *hexaster* and *D. hexaster* subsp. *helvetica* on the basis of poorly developed shapes at the ends of the branches.

Besides his first determinations of various genera in the Dinarides and their stratigraphic distribution, Herak was also concerned about phylogenetic relationships as well as significance of morphological characteristics in taxonomy. Herak was well aware of many difficulties in phylogenetic reconstructions within various taxa, and thus he exploited the significance of morphological features in taxonomy. Herak is critical of the usage of small and gradual morphological differences in the delineation of taxa and he is of the opinion that establishment of subspecific variation is more appropriate than the foundation of new taxa, as such units could be more easily revised and defined. With the introduction of such a theoretical approach Herak emphasized the necessity of application of the taxonomic criteria and his theoretical frameworks are still valid.

Herak considered calcareous algae and their importance in the stratigraphy of the Late Palaeozoic and Mesozoic of the Dinarides in several papers (HERAK, 1960, 1966). Along with listing sites in Dinarides where all previously established species of gymnocodiacean, codiacean and dasycladacean algae have been discovered, and their stratigraphic position, he added new data with established changes to stratigraphic distribution. For several species, he extended their stratigraphic range, considered the range previously known (e.g. *Permocalculus tenellus* has been extended to Early Permian, etc.), and he also commented upon the taxonomy of the genera *Anthracoporella*, *Vermiporella*, *Permocalculus*, *Epimastopora*, etc. For several species of the genus *Permocalculus* (*P. fragilis*, *P. monoliformis* and *P. solidus*) Herak considered unifying them under the name *P. fragilis*. In his overviews, presented also at international meetings, Herak has integrated the results previously achieved by several authors, which enabled the European algal society to become acquainted with Croatian ranges and our contribution to the research of the fossil calcareous algae at the critical time.

As a competent and established expert in calcareous algae, Herak has worked on the taxonomic and stratigraphic interpretation of samples from Slovenia, Austria and Greece, incorporating his results into the interpretation of regional geological settings as a base for speculations over the tectonic and hydrogeologic settings. He has described several species, subspecies and variations of dasycladacean algae, especially the Triassic ones. These include *Physoporella minutoloidea* HERAK 1967; *Ph. likana* HERAK 1965; *Ph. croatica* HERAK 1958; *Diploporella subtilis* PIA var. *graeca* HERAK 1967; *D. annulata* subsp. *annulata* (PIA 1920) HERAK 1957; *D. annulata* subsp. *dolomitica* HERAK 1957 and *Cayeuxia mediterranea* HERAK 1967 from the cyanophycean group.

As previously mentioned, most of Herak's papers have been directed toward stratigraphic determination, defining the distribution and mutual relationship between previously poorly defined complexes of deposits and their facies in the Late Palaeozoic, and particularly the Triassic. This understanding of fossil calcareous algae has enabled for the first time the definite division of the Middle Triassic of the part of Lika below the Velebit Mt.; the establishment of the Anisian and Ladinian at numerous localities in the Outer Dinarides; the development of clastic facies of both the Middle Triassic stages, as well as defining the entire range of certain taxa and whole algal communities. Also, all of these papers, even smaller volumes, contain some palaeontologic and taxonomic novelties. Reports of the finds of some species, including isolated species, in the area of the Dalmatinska Zagora, Lika, Kordun, Hrvatsko Zagorje and the mountains of Slavonia, are also valuable because these finds stimulated later researchers to collect this precious material, enabling more comprehensive elaboration of calcareous algae within the entire Mesozoic and even part of the Palaeogene. The "algae" *Sphaerocodium bornemanni* ROTHPLETZ (see HERAK, 1952, 1957a) remains a valid indicator of shallow-sea sedimentation in the Upper Triassic due to its morphology, definition of original palaeoenvironment, method of decay and visual characteristics.

Significant papers from the algal opus of Herak are also the result of collaboration. In co-authorship with the late professor V. Kochansky-Devidé (HERAK & KOCHANSKY-DEVIDÉ, 1960; KOCHANSKY-DEVIDÉ & HERAK, 1960) the calcareous algae of the Late Palaeozoic of Velebit Mt., as well as samples from the sites in Gorski Kotar, Slovenia, Serbia and Montenegro, were described. New taxonomic contributions were provided by description of the new genus and species *Clavaporella caliciformis* and several new species of previously known genera including *Anthracoporella vicina*, *Mizzia cornuta*, *Epimastopora likana*, *E. alpina* and *Diploporella pusilla*. The morphogenetic comparison for the species *Anthracoporella spectabilis* PIA and newly-described *Anthracoporella vicina* was shown. The comparative analysis of several species of the genus *Vermiporella* was carried out, suggesting that *V.*

velebitana is probably younger synonym of the species *Gymnocodium bellerophontis*. The description of the species *Vermiporella serbica* PIA was expanded, and the genus *Epimastopora*, despite unclear morphogenetic characteristics, was extended with two previously mentioned species (*E. likana* and *E. alpina*). The uncertainty of the genus *Hicorocodium* (*H. elegante* ENDO), the organization of which is atypical of dasycladacean algae, was highlighted.

The paper by HERAK et al. (1977) entitled "The Development of the Dasyclad Algae through the Ages" is among the significant contributions in calcareous algae palaeontology, due to its evaluation and observation of morphogenetic features of algal evolution along with consideration of the phylogeny. Based upon the 29 morphological features, accompanied by their age, the correlation of 80 suitable genera was carried out. The authors proved that the continuity level of a certain feature corresponds with its regularity, and is opposite to the level of differentiation and specialisation. The attitude that the increase in differentiation is the result of evolutionary changes, and that fossil dasycladaceans could be gathered into several morphogenetic evolutionary levels, with their representatives dispersed in time, has been expressed. Based upon these features, five groups have been formed, which include some common characteristics. The sequence of the separated groups through the geological past, also shows the evolution from the first group with the most primitive features to the fifth group, the youngest, with differentiated and specialised features. The application of these features enabled not only the classification of the main genera of fossil dasyclad algae, but also the infilling of some gaps, by checking the type material of some doubtful genera. This paper has remained valid as an analysis of morphogenetic characteristics, their development, differentiation and specialisation in the phylogenetic succession.

On the occasion of this anniversary, when we celebrate and acknowledge the long-standing, rich opus that academician Herak leaves us, we cannot emphasize enough his contributions to palaeontology and geology, especially in the field of calcareous algal research. Numerous citations of Herak's papers in Croatian and, even more often, foreign publications, as well as the naming of several taxa after Herak by some authors, could serve to emphasise the acknowledgement and value of Herak's papers. These taxa are: *Physoporella heraki* var. *heraki* BYSTRICKÝ 1967; *Ph. heraki* var. *tenuipora* BYSTRICKÝ 1967; *Cymopolia heraki* GUŠIĆ 1967, later denoted as a younger synonym of *C. mayaense* JOHNSON & KASKA 1965, after DELOFFRE & RADOIČIĆ (1978); *Petrascula ?heraki* SOKAČ & NIKLER 1969; *Herakella paradoxa* KOCHANSKY-DEVIDÉ 1970; *Hexaella heraki* MILANOVIĆ 1989 and *Asterocalculus heraki* SOKAČ & GRGASOVIĆ 1998.

Working on the fossil algae from several European localities and publishing his papers in several foreign

journals and occasional publications, professor Herak has offered the European and global palaeontological community an insight into the Croatian approach and achieved results in the palaeontological and stratigraphic investigations of the fossil calcareous algae. With his comprehensive, but also differentiated approach to the series of open questions in the field of taxonomic, phylogenetic and stratigraphic domain of fossil calcareous algae, Herak has initiated and guided (together with professor Vanda Kochansky-Devidé) the path which remains in the papers of later researchers, and which is today in the European algal community frequently called "The Zagreb algal school".

His devotion to palaeontology is revealed in the preparation and publication of the textbook "Palaeobotany" (HERAK, 1953, 1963). Besides its assignment to the students of geology and biology, the aim of this textbook was to introduce a wider society of readers to palaeobotanical issues, and to get them acquainted with the most typical plants from the geological past and their influence in geological processes.

He also published many popular articles in "Priroda", in the edition "Znanje i radost", in "Zadružni kalendar" etc., acquainting everyone with the basic ideas and meanings of palaeontology, palaeobiology and geology in general.

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