

Professor Herak's Contribution to Regional Geology and Geotectonics

Josip BENIĆ¹, Ivan BLAŠKOVIĆ² and Vladimir TOMIĆ³

A deep insight into the stratigraphy and regional geology of many countries from several continents, as well as acquaintance with geotectonical references and experience from many detailed field explorations of "crucial cases" gave Herak an original attitude and unique way of approaching geotectonic problems.

Although global tectonics was never actually his primary scientific objective, some practical problems persuaded Herak of the necessity to understand the structural relationships of any studied area.

The first scientific contributions of global tectonics extend to the early days of Herak's career. Apart from an acquaintance with stratigraphy, practical problems mostly of a hydrogeological nature required explanation of the structural relationships in the investigated areas. Thus, as early as 1959, in his paper on the geology and hydrogeology of the island of Hvar, the underground water system of the island was explained with the aid of a delimited anticline. Only a year later, by disclosing the Middle Triassic anticline in the Ričica polje he elucidated the mechanism of sinking and upwelling of the local groundwaters (HERAK, 1960). Apart from its scientific contribution, the latter was also important in planning the accumulation basin of the Obrovac electric plant.

It seems that the significant moment for Herak's geotectonic inclination occurred in 1961, when he studied geological relationships in the upper course of the Kupa river, with the purpose of investigating possibilities for the accumulation of water. It was then that Herak and his coworkers published the paper "New elements of tectonics in the upper course of the Kupa river". Instead of being autochthonous with Palaeozoic anticlinal cores, they discovered that both Palaeozoic and Triassic sediments lay allochthonously over Jurassic carbonate rocks. He exposed his vision of tectonic upheavals in the Dinarides at the International Congress in Bar in 1971. One should not overlook the scientific paper on the tectonic interpretation of evaporites of the

Dalmatian Zagora, either (HERAK, 1973). He later reinterpreted this idea in his capital work on tectonics published in 1986, in which the thrusts from the northeast had been substituted with continental subduction from the southwest, that is, with subduction of the Adriatic beneath the Dinaric plate, taking into consideration his observations from earlier work. From then on, Herak was no longer satisfied with the numerous geotectonic models that describe the structure of the Dinarides based on the theory of geosynclines with double orogeny. He understood that something must be radically changed in the basic concepts of Dinaric geotectonism. Painstakingly collecting the field data, analysing them, and reevaluating all accessible data, particularly in the area of Gorski Kotar, Velebit Mountain and Lika, Herak discovered the existence of allochthonous tectonics in the regions formerly treated entirely as autochthonous in origin. He reconstructed the mechanism of movement with two cardinal issues: a) the cause of movement must be sought much deeper ("subcrustally"), while subduction is directed toward the northeast and obstructed from within the crustal zone; b) the intensity of allochthony increases with the depth.

This point of view is basically different from co-existing opinions, because all geotectonic concepts about the structure of the Dinarides held that the thrusting was directed from the northeast toward southwest. All this was exposed as early as 1980 in his first pioneering work based on mobilistic ideas: "The system of nappes between Vrbovsko and Delnice in Gorski Kotar (Hrvatska)" (HERAK, 1980). Today, there is no doubt that Herak had already presupposed the continental subduction (A-subduction) which, although under different name, would later imprint the tectonics of the Dinarides.

Since 1980 Herak has been directing his scientific curiosity increasingly to the elucidation of the geotectonic problems of the Dinarides. Although subductions on the ocean margins were in those days the primary

¹ Institute of Geology, Sachsova 2, P.O. Box 268, HR-10000 Zagreb, Croatia.

² Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva 6, HR-10000 Zagreb, Croatia.

³ Department of Geology and Palaeontology, Faculty of Science, University of Zagreb, Ul. kralja Zvonimira 8, HR-10000 Zagreb, Croatia.

This paper was presented at the scientific meeting dedicated to the 80th anniversary of the life of Professor Milan Herak, held on March 5th, 1997 in Zagreb

focus of scientific interest, he presupposed simultaneous subductions among separate parts of the continental crust.

Having realized that an ample conceptual diversity describing the tectonics of the Dinarides can not be reduced to some already recognized common model, he preferred to announce his own idea of regional tectonics. Exploring the available literature he recognized that the concept of plate tectonics had displaced completely the classic concept of fixism all over the world. Therefore he tried to discover new geotectonic definitions for our Croatian regions as well as abroad. By 1986, Herak brought to light a new concept of genesis and structure of the Dinarides ("A new concept for the geotectonics of the Dinarides") (HERAK, 1986), suggesting an alternative for the two principal geotectonic units, mostly called the "Outer" and "Inner Dinarides", and supplanting them by the four palaeoambiental and palaeodynamic belts. These are really four independent palaeogeographic units with appointed significance of corresponding paleodynamic units in the period of development and structural formation. This is precisely where interdependence has been observed between regional geology, which is a basis for the definition of palaeogeographic units, on one side, and geotectonics on the other, as far as similar behaviour of the newly promoted units in the stages of structural formation is concerned. Extending continuously from the Peloponnese to the Southern Alps these palaeogeographic units are aligned as follows: "Adriaticum", "Epiadriaticum", "Dinaricum", and "Supradinaricum", each with its specific attributes. They occupy mutually allochthonous positions brought about by continental subductions of certain units under others. Reinterpreting all accessible data from numerous localities and correlating the relief of the Moho discontinuity with tectonic configuration, Herak in his subsequent works substantiated his earlier conclusion concerning pronounced mobilism as a reason for the origin of allochthonous structures in the broader area of the Dinarides. This idea gradually prevailed through the tectonic literature, resulting in the reexamination of many previous theories about the structure of locally confined areas, and sometimes their correction.

The widespread geological community sometimes considers Herak's ideas daring and revolutionary, but only because the whole concept represents the fruit of long-lasting reflections and thought on the basis of bonding theory and experience. The scientific results he has accomplished were promptly utilized in practice, while, in turn, he subsequently used applied geological results to supplement and improve the fundamental geological scientific principles.

REFERENCES

- HERAK, M. (1959): Prilog geologiji i hidrogeologiji otoka Hvara (Zur Geologie und Hydrogeologie der Insel Hvar).- *Geol. vjesnik*, 12 (1958), 135-148.
- HERAK, M. (1960): Geologija Gračačkog polja u Lici (Geologie des Karst Polje von Gračac in der Lika, Kroatien).- *Geol. vjesnik*, 13 (1959), 31-56.
- HERAK, M., BOJANIĆ, L., ŠIKIĆ, D. & MAGDALENIĆ, A. (1961): Novi elementi tektonike u području gornjeg toka rijeke Kupe (Neue Elemente der Tektonik im Gebiet des Oberlaufs des Kupa-Flusses).- *Geol. vjesnik*, 14 (1960), 245-251.
- HERAK, M. (1971): Beitrag zur Rekonstruktion der orogenetischen Dynamik in der Dinariden Kroatiens.- I simp. o orog. fazama u prostoru Evrope, Beograd-Bor (1970), 35-40, Beograd.
- HERAK, M. (1973): Some tectonical problems of evaporitic area in the Dinarides of Croatia (Neki tektonski problemi pojasa s evaporitima u Dinaridima Hrvatske).- *Geol. vjesnik*, 26 (1972), 29-40.
- HERAK, M. (1980): Sustav navlaka između Vrbovskog i Delnica u Gorskom kotaru - Hrvatska (The nappe-system between Vrbovsko and Delnice in Gorski Kotar - Croatia).- *Acta geol.*, 10/2, 35-51, Zagreb.
- HERAK, M. (1986): A new concept of geotectonics of the Dinarides (Nova koncepcija geotektonike Dinarida).- *Acta geol.*, 16/1, 1-42, Zagreb.
- HERAK, M. (1991): Dinaridi - Mobilistički osvrt na genezu i strukturu (Dinarides - Mobilistic view of the genesis and structure).- *Acta geol.*, 21/2, 35-117, Zagreb.

Doprinos prof. Heraka regionalnoj geologiji i geotektonici

Dobro poznavanje stratigrafije i regionalne geologije mnogih zemalja na više kontinenata, poznavanje literature o geotektonici, te iskustvo s brojnih terenskih detaljnih istraživanja "ključnih terena", omogućili su profesoru M. Heraku originalan pristup pri rješavanju geotektonskih problema.

Iako mu šira tektonika svojedobno i nije bila u prvom planu njegovog znanstvenog interesa, pojedini praktični zadaci su ga uvjerili u nužnost poznavanja strukturnih odnosa istraživanih terena.

Prvi znanstveni doprinosi iz šire tektonike sežu u mlade dane profesora Heraka. Praktični zadaci vezani uglavnom uz hidrogeološku problematiku tražili su, uz poznavanje stratigrafije, i rješavanje strukturnih odnosa istraživanih terena. Tako nalazimo već 1959. godine u znanstvenom radu o geologiji i hidrogeologiji otoka Hvara da uz pomoć utvrđene antiklinale objašnjava podzemne vode otoka, a slijedeće godine u Ričičkom polju otkrivanjem srednjotrijaske antiklinale objašnjava mehanizam ponornih i izvorišnih voda, što je uz znanstveni doprinos bilo vrlo važno i za projektiranje akumulacijskog bazena hidroelektrane Obrovac.

Čini se da je značajan trenutak za geotektonsko usmjerenje bila 1961. godina pri proučavanju geoloških odnosa u gornjem toku rijeke Kupe u cilju određivanja mogućnosti akumuliranja vode, kada prof. Herak i suradnici objavljuju rezultate u radu "Novi elementi tektonike u području gornjeg toka rijeke Kupe". Umjesto autohtonije s paleozojskim jezgrama antiklinala, utvrdili su da su i paleozojske i trijaskke naslage alohtone na jurskim karbonatnim naslagama. Slijedi niz radova vezan na stratigrafiju i hidrogeologiju, da bi 1971. na Međunarodnom simpoziju u Boru izložio svoje viđenje tektonskih promjena u Dinaridima. Ne smije se preskočiti ni 1973. godine publicirani znanstveni rad o tektonskoj interpretaciji evaporita Dalmatinske zagore, koji u svom kapitalnom tektonskom radu 1986. godine reinterpretira zamijenivši kretanja sa sjeveroistoka kontinentalnom subdukcijom s jugozapada, tj. podvlačenjem Adrijatika pod Dinarik uz uvažavanje svojih zapažanja iz starijeg rada. Od tada M. Heraka više ne zadovoljavaju brojni geotektonski modeli grade Dinarida bazirani na teoriji geosinklinala s dvostrukim orogenom. Shvatio je da se u osnovnim poimanjima geotektonike Dinarida mora nešto iz korijena mijenjati. Strpljivim prikupljanjem terenske faktografije i njihovom analizom, te revidiranjem postojećih podataka, prvenstveno u području Gorskog kotara, Velebita i Like, otkriva prisutnost alohtone tektonike u područjima koja su do tada tretirana isključivo kao autohtona. Rekonstruirao je mehanizam kretanja, gdje su bitna dva zaključka:

a) uzrok kretanja treba tražiti dublje ("subkrustalno"), podvlačenje je prema sjeveroistoku uz otpore u krustalnom dijelu; b) intenzitet alohtonije povećava se od površine prema dubini.

Takav pristup je dijametralno suprotan dotadašnjim shvaćanjima, jer se u svim geotektonskim koncepcijama o gradi Dinarida smatralo da su kretanja bila od sjeveroistoka prema jugozapadu. Sve je to rečeno u njegovom prvom (pionirskom) radu baziranom na mobilističkoj osnovi već 1980. god.: "Sustav navlaka između Vrbovskog i Delnica u Gorskom kotaru (Hrvatska)". Čitajući danas taj rad jasno nam je da je profesor Herak pretpostavio kontinentalnu subdukciju (A-subdukciju), iako je tada nije tako nazvao, a koja će kasnije obilježiti tektoniku Dinarida.

Svoj znanstveni interes M. Herak je od tada sve više usmjeravao na rješavanje geotektonskih problema Dinarida. Iako se u to vrijeme pretežito govori o subdukcijama na rubovima oceana (B-subdukcije), u Dinaridima pretpostavlja međusobne subdukcijske procese dijelova kontinentalne kore.

Uvidjevši da veliku raznolikost ideja o tektonskoj gradi Dinarida ne može svesti na neki poznati zajednički model, te da takve interpretacije nemaju realnu potvrdu u terenu, odlučio se za svoju viziju o tektonskoj gradi toga prostora. Proučavajući aktualnu literaturu uvidio je da koncepcija o tektonici ploča posvuda u svijetu preuzima položaj klasičnih koncepcija fiksizma, te je zato na tim osnovama pokušao naći nova geotektonska rješenja za naš hrvatski prostor i šire. I konačno - 1986. godine profesor Herak iznosi novu koncepciju o genezi i gradi Dinarida ("A New Concept of Geotectonics of the Dinarides"), gdje predlaže zamjenu dviju glavnih geotektonskih jedinica, koje se najčešće nazivaju "Vanjski" i "Unutrašnji Dinaridi", s četiri paleoambijentalna i paleodinamska pojasa. To su zapravo četiri izdvojene paleogeografske jedinice kojima je dat značaj paleodinamskih jedinica u razdoblju razvoja i strukturnog formiranja. I upravo ovdje se vidi povezanost regionalne geologije, kao osnove određivanja paleogeografskih jedinica i geotektonike u smislu približno sličnog ponašanja tih jedinica u fazama formiranja struktura. Te se jedinice kontinuirano pružaju od Peloponeza do Južnih Alpa. To su: "Adrijatik", "Epiadrijatik", "Dinarik" i "Supradinarik", a odlikuju se nekim specifičnim značajkama. Medusobno su u alohtonim položajima izazvanim kontinentalnim subdukcijama jednih jedinica pod druge. U svojim kasnijim radovima M. Herak reinterpretacijom dosadašnjih postojećih podataka s brojnih lokaliteta i korelacijom između reljefa Mohorovičićeva diskontinuiteta i tektonske grade

potvrđuje svoj raniji zaključak o izrazitom mobilizmu kao uzročniku alohtonih struktura u širem području Dinarida. Ideja postupno, ali sigurno ulazi u našu tektonsku literaturu, tražeći preispitivanje mnogih dosadašnjih shvaćanja struktura uže omeđenih terena, u cilju uzajamnog oplodivanja, pa i korekcija.

U prebogatim i raznovrsnim znanstvenim radovima profesora Heraka, geotektonski radovi postaju u zadnjih

10-ak godina začuđujućom brzinom po opsegu i dubini ulaženja u problematiku središnji interes profesora. Samo za širu geološku javnost to su smjeli i revolucionarni potezi, jer sve je to plod dugogodišnjih razmišljanja i sazrijevanja ideja na osnovi spajanja znanosti i prakse, gdje znanstvene rezultate izravno primjenjuje u praksi, a s praktičnim geološkim rezultatima nadopunjava i korigira fundamentalnu geološku znanost.