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The role of the calcareous breccias (Jelar Formation) in the tectonic interpretation of the High Karst Zone of the Dinarides

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Heterogeneous carbonate breccias which have been attributed to widely differing chronostratigraphic units (Middle Jurassic to Neogene) are considered to be a Tertiary »Wildflysch«. This interpretation will require a re-examination of the evolution of the tectonic patterns of central Lika (Croatia.)

INTRODUCTION

One of the most unusual lithostratigraphic units of the High Karst Zone of the Dinarides, especially in the Lika and Mt. Velebit areas, is a succession of calcareous breccias and minor conglomerates. They are present particularly in the central region of Lika, the area of Mt. Crnopac, and on the southwestern slope of Mt. Velebit where they, locally, reach a thickness in excess of 300 m. Classically, the breccias have been considered to be a Middle Cretaceous lithostratigraphic unit, which nonconformably overlies a Jurassic carbonate sequence.

Detailed research, spanning the last two decades, involving mapping projects concerned with the preparation of the Basic geologic map of S. F. R. Yugoslavia, and with many industrial project studies, has clearly shown the age of these breccias to be in part Paleogene. During this same time interval, a series of new areas have been registered and chronostratigraphically dated on the basis of breccia fragments included to be of Middle Jurassic to Paleogene (rarely even Early Neogene) in age. The Paleogene areas have been normally considered to be the time equivalent of the Promina beds (conglomeratic molasse deposits). Bahun (1963) proposed the name Jelar deposits for the breccias in view of the fact that they were different in composition and that there was no proof for their correlation with the Promina beds.

The genesis of the breccias, particularly those attributed to the Mesozoic Erathem, have had numerous origin possibilities postulated for them; three well known concepts are: the time equivalents of evaporitic sequences (Šušnjar et al., 1965); the consequence of local and regional disturbances at different time intervals (sections of the Basic geologic map); and the result of geotectonic disturbances at the »transverse« tectonic zone, extending from Split to Karlovac (Chorowicz, 1977).

These widely divergent differences in interpretation required a re-examination and re-evaluation of some unsolved problems and the consequent dilemmas concerning calcareous breccias and their correlation with other rock complexes. The Basic geologic map, displaying excellent research data, greatly facilitated our field examination as well as clearly defining the basic problem.

DISTRIBUTION OF THE BRECCIAS

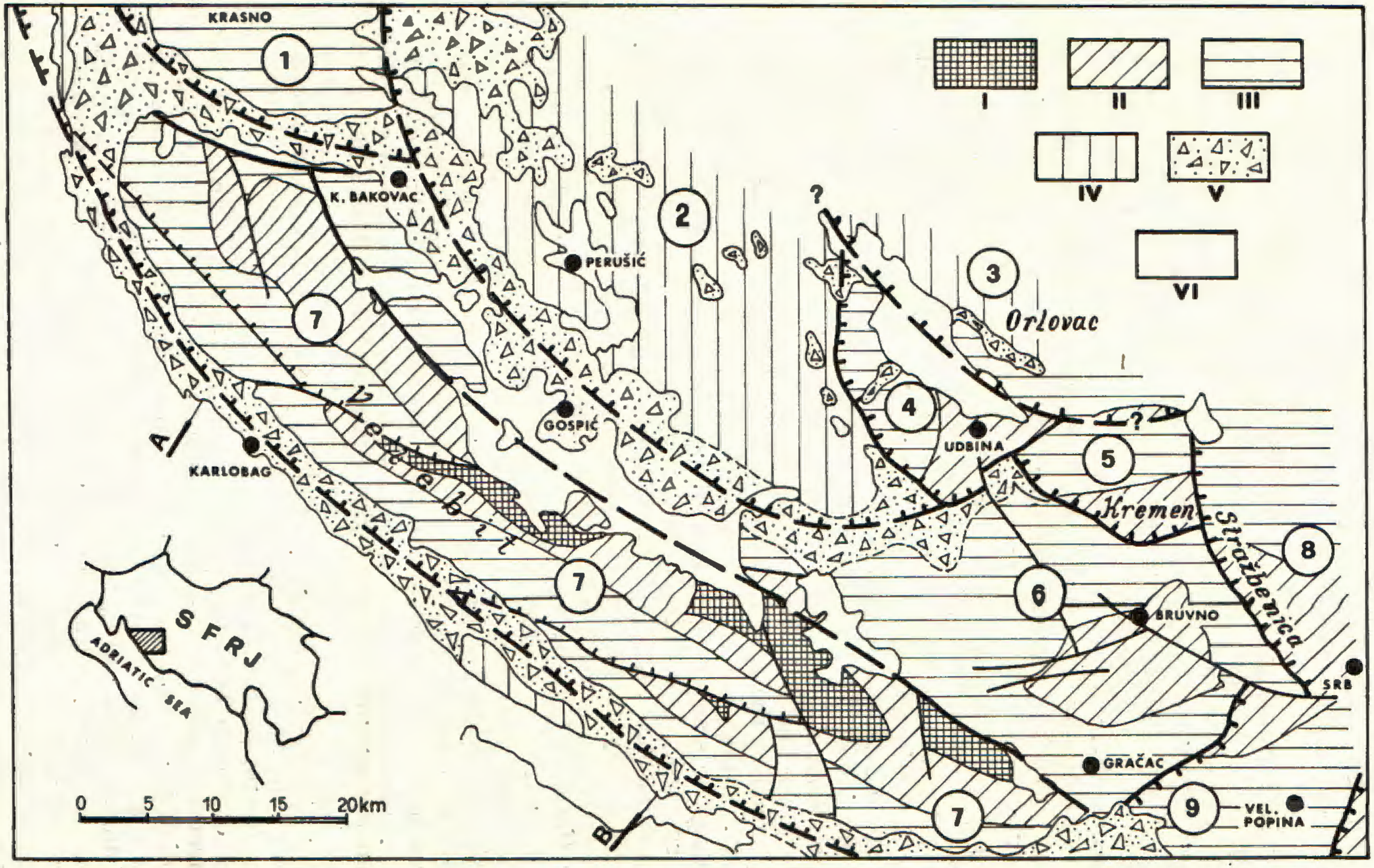
Ivanović et al. (1967) and Chorowicz (1977) dealt with problems involving »monogenetic« breccias consisting of Jurassic fragments which were intimately related to carbonate terraines. The conclusion that they are synsedimentary eliminate them from our discussion.

The fundamental problem is concerned with heterogeneous (»polygenetic«) breccias that consist of heterochronous material, ranging from the Triassic to the Paleogene in age, which are widely distributed in Lika (Text-fig. 1).

Triassic components of the breccias are overwhelming near the contact with the thrust unit in the vicinity of Udbina. Jurassic fragments, present along the road from Udbina to Lovinac, mark the transition zone from the Jurassic to the Cretaceous. In the vicinity of Cretaceous areas (primarily Upper Cretaceous) Jurassic and Lower Cretaceous components prevail. In very numerous isolated areas overlying Triassic, Jurassic and Cretaceous terrains, breccia components of Jurassic, Cretaceous and Paleogene limestones are observed. These compositional differences, plus the proximity of the precisely determined carbonate lithostratigraphic units, were the basis for the age determination of the breccias (Barremian, Lower Cretaceous, Albian-Cenomanian, Paleogene-Neogene). In some areas, the same units have been given different ages. That problem might be involved with the determination of recycled (»second generation«) rock fragments. The contact of the breccias with the other lithostratigraphic units are unclear and have been considered mostly as transgressive or not precisely determined. Discordant contacts should exist even between two differently dated breccia complexes. Field evidence does not support this presumption. The geotectonic disturbances, required to support the current genetic concept of heterogeneous breccias, need repeated intense local orogenic events, involving limited areas extending from the Triassic to the end of the Paleogene in time. The lack of substantiative field evidence, with regard to disconformity and the erection of an unlikely unique, locally pulsating tectonic model, would seem to invalidate the current concept. It is on this basis that we offer an alternate interpretation for the genesis of the heterogeneous breccias.

GENESIS OF THE BRECCIAS

It is reasonable to conclude that the heterogeneous breccias which are composed of Triassic, Jurassic, Cretaceous and Paleogene fragments would have available lithostratigraphic units, down to the Lower Triassic, to act as areas of provenance. In some small breccia distribution areas



Text-fig. 1. Distribution of breccias in relation to different stratigraphic complexes and tectonic units (established and inferred); I Paleozoic, II Triassic, III Jurassic, IV Cretaceous, V Jelar beds, VI Quaternary; 1—9 tectonic units: 1 = Krasno, 2 = Perušić, 3 = Orlovac, 4 = Udbina, 5 = Kremen, 6 = Bruvno, 7 = Velebit, 8 = Stražbenica, 9 = Vel. Popina.

Sl. 1. Rasprostranjenost breča u odnosu prema različitim stratigrafskim kompleksima i tektonskim jedinicama (ustanovljenim i pretpostavljenim): I paleozoik, II trijas, III jura, IV kreda, V Jelar-naslage, VI kvartar; 1—9 tektonske jedinice: 1 = Krasno, 2 = Perušić, 3 = Orlovac, 4 = Udbina, 5 = Kremen, 6 = Bruvno, 7 = Velebit, 8 = Stražbenica, 9 = Velika Popina.

the units could not be exposed by erosion alone. Local tectonic disturbances could not intensify the process of erosion enough to reach so deeply as to cause the abnormal contacts of the differently dated complexes of breccias, the observable relationships between the breccias, or with other lithostratigraphic units. The fact that the rock sequences, in the vicinity of the breccias, are more or less conformable indicates that large areas cannot be tectonically disturbed. Lacunae without angular discordance testify to the concept that from the Upper Triassic to the end of the Cretaceous, predominantly epeirogenic movements existed with local disturbances, which contributed to the genesis of intrabasinal »homogeneous« breccias related to carbonate rocks of different ages.

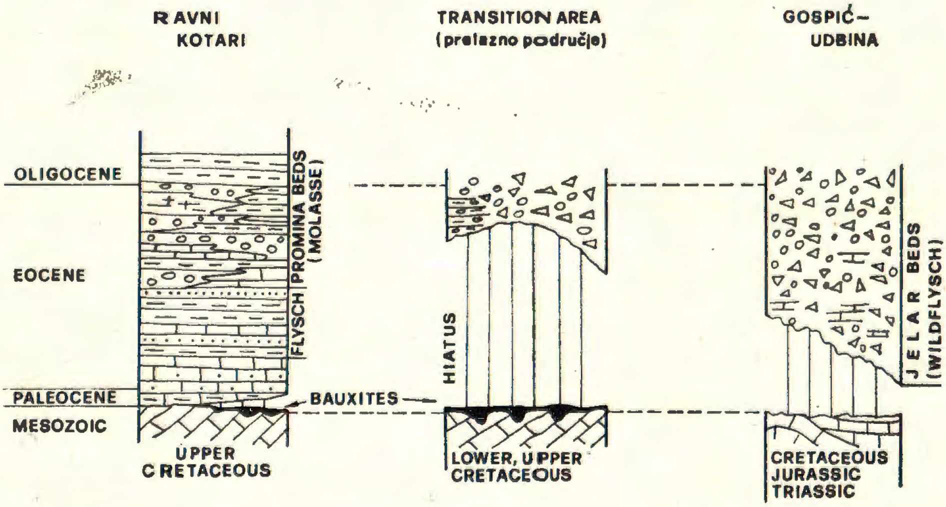
The accumulation of several complexes of heterochronous breccias, superimposed on each other, was not possible. Therefore, their genesis requires an alternative explanation. The contacts are completely veiled. The age of fragments is not valid in that respect. The cement has not yielded reliable index fossils. Therefore, there are no reasons to negate the concept that all the heterogeneous breccias are components of only one major lithostratigraphic complex which was formed during a single major orogenic event (occurring in several phases). The end of the process of formation of the breccias could not be older than the Paleogene components. Several factors can be cited for such a conclusion.

Local lacunae and the fresh or brackish water »Liburnian« facies, at the beginning of the Paleogene, strongly argue the point of Laramide folding and faulting, as clearly demonstrated by Polšak (1971) and others. Paleogene marine deposition (limestone and flysch) occurs in depressions sporadically connected by channels. The subsidence of these new sedimentational areas is demonstrated by the wider horizontal extension of the flysch deposits in relation to the underlying limestone. Basinal development was synchronously accompanied by structural disturbances (folding, faulting and »crushing«) of the emerged carbonate terrains which acted as source areas for the carbonate components of the flysch. Anticlinal clastic cores, if exposed, would act as a source for silt and clay size particles. Tensionally jointed crests of the anticlines were suitable not only for providing small particles which could be distally transported to the flysch basins but also larger and variable fragments of debris which could be deposited proximally on the eroded crests, dependent on the dynamics of the sedimentation process. The small area of bauxites that lies between the Paleogene basin of Ravni Kotari and the folded carbonate terrains is intepreted as having remained uncovered for a longer time and, therefore, was suitable, under favorable climatic conditions, for the genesis of bauxites.

The end of flysch deposits, in the coastal belt, was introduced by stronger tectonic activity. The basins show evidence of at least being partially disturbed (folding, reverse faults). The adjacent carbonate terrains of the High Karst Zone were submitted to extensive, strong tangenital disturbances. Consequently, many of the folds were overturned toward the southwest and accompanied by differentially oriented oblique, transverse and rotational faults and thereby causing the differences in the rates of tangentional movements. Under these conditions vertical displacements were converted to overthrusts accompanied by the décollement type of thrusts over already eroded terrains composed of rocks of different ages. Simultaneously rock fragments from all exposed rock complexes were gravitationally transported and laid down more or less distantly from the front of the thrust units and the cores of the anticlines.

Disintegrated thrust sheets were areas for extensive slumping of large and even composite blocks (locally preserving original bedding). These blocks are responsible for most of the interpreation troubles so far encountered. Redepositing of rock fragments occurred so as to negate the law of superposition by placing older rocks above younger ones. It is possible, therefore, that Upper Cretaceous fragments would be overlain by Lower Cretaceous or even Jurassic fragments. This set of conditions explains the field phenomena in which breccias contaning Paleogene fragments seem to underlie those consisting of only Mesozoic components. The breccias composed of Triassic and Jurassic components seem to lie close to their source areas (eroded anticlinal cores or fronts of subsequent thrust sheets). The timing of the event, which caused an intensified redeposition and accumulation of rock fragments in the High Karst Zone, would seem to be the Upper Eocene. This event would also account for the carbonate conglomeratic components of the Promina beds which were deposited over the flysch, Eocene limestones, Cretaceous limestones and bauxites (Text-fig. 2).

The proposed concept of the genesis of the heterogeneous calcareous breccia distinguishes the Promina beds from the Jelar formation (Wildflysch). Heterogeneous breccias, it should be remarked, are so mutually interrelated with homogenous breccias and with some Jurassic and Cretaceous limestones that the impression of their genetic relationships could not be overlooked. The conclusion should be that heterogeneous



Text-fig. 2. Geologic columns showing the differences in genesis of Jelar breccias and Promina beds.

Sl. 2. Geološki stupovi koji pokazuju razlike u nastanku Jelar-naslaga i Promina-naslaga.

breccias were deposited on terrains that were already tectonically disturbed and eroded and, thereby, displaying outcrops of variant lithologic units probably including the homogeneous breccias. The basic problem is in the recognition of tectonic and normal contacts which in this instance is very difficult.

Analogously, it is also possible to explain cases where some Jurassic (or Cretaceous) limestones, apparently, grade into breccias which contain Upper Cretaceous and Eocene fragments as proof of their Tertiary age. An excellent example of this situation occurs near Baške Oštarije, on the ridge of Mt. Velebit, where an apparently continuous sequence of Upper Jurassic limestone with *Clypeina jurassica* occurs over homogeneous breccias grading into heterogeneous breccias containing Cretaceous fragments. The sequence is, of course, discontinous. Applying our concept, the solution would be to fill up the fractures of younger heterogeneous variegated breccias with older fragments. Where the younger breccia is a constituent of that one consisting of Jurassic and Lower Cretaceous fragments the Jurassic or Lower Cretaceous age of the last mentioned breccias is excluded (fig. 3).

CONCLUSIONS

Heterogeneous breccias with some conglomeratic components (so far attributed to a sequence of tectonic events ranging from the Middle Jurassic to the Neogene) are products of orogenic disturbances and erosion. We consider these breccias to be of Tertiary (mostly Paleogene) age and contemporaneous not only with the Promina beds but also with the greater part of the underlying flysch.

The proposed model of the breccias and their chaotic appearance (with extensive slumping) speaks in favor of consideration of the fact that they are a calcareous analogue to the Wildflysch rather than to the molasse.

This concept eliminates many stratigraphic correlation problems with areas lacking breccias. The documented small breccia areas, preserved within Upper Cretaceous synclines without marginal faults, may be logically explained following this model.

The establishment of a Tertiary age for heterogeneous breccias allows the continuation of a number of major faults (including thrusts) below the breccias. This will enable the reconstruction of a more viable suite of tectonic units that heretofore have remained only partially defined. The major impact of the concept is in the extension of the thrust contacts below the breccias (Text-fig. 1), which leakes the entire structural relationship of the area open reinterpretation (Text-fig. 4).

It seems hardly necessary to point out that our approach and atempt at tectonic reconstruction of the area in question will need additional discussion, verification or emendation, on the basis of new research in adjacent east and west areas, since the principle of setting has to be identical.

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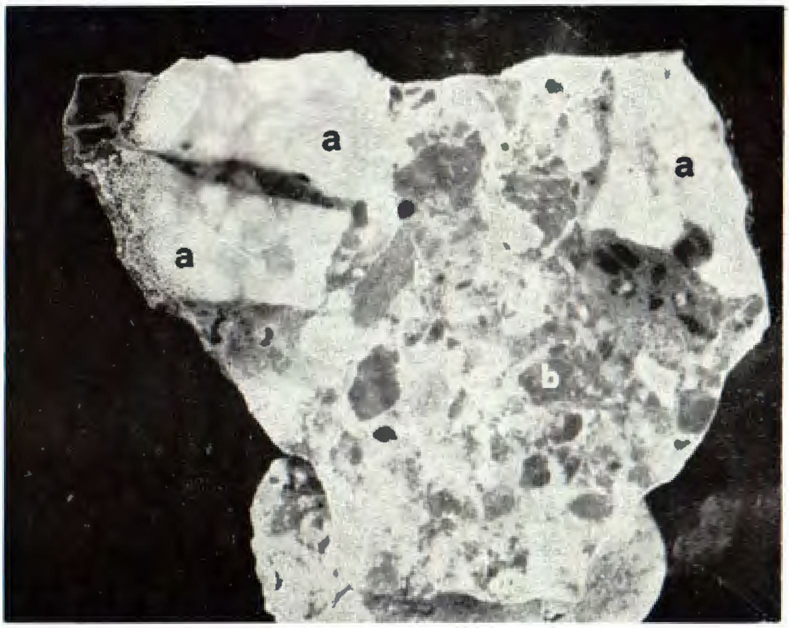
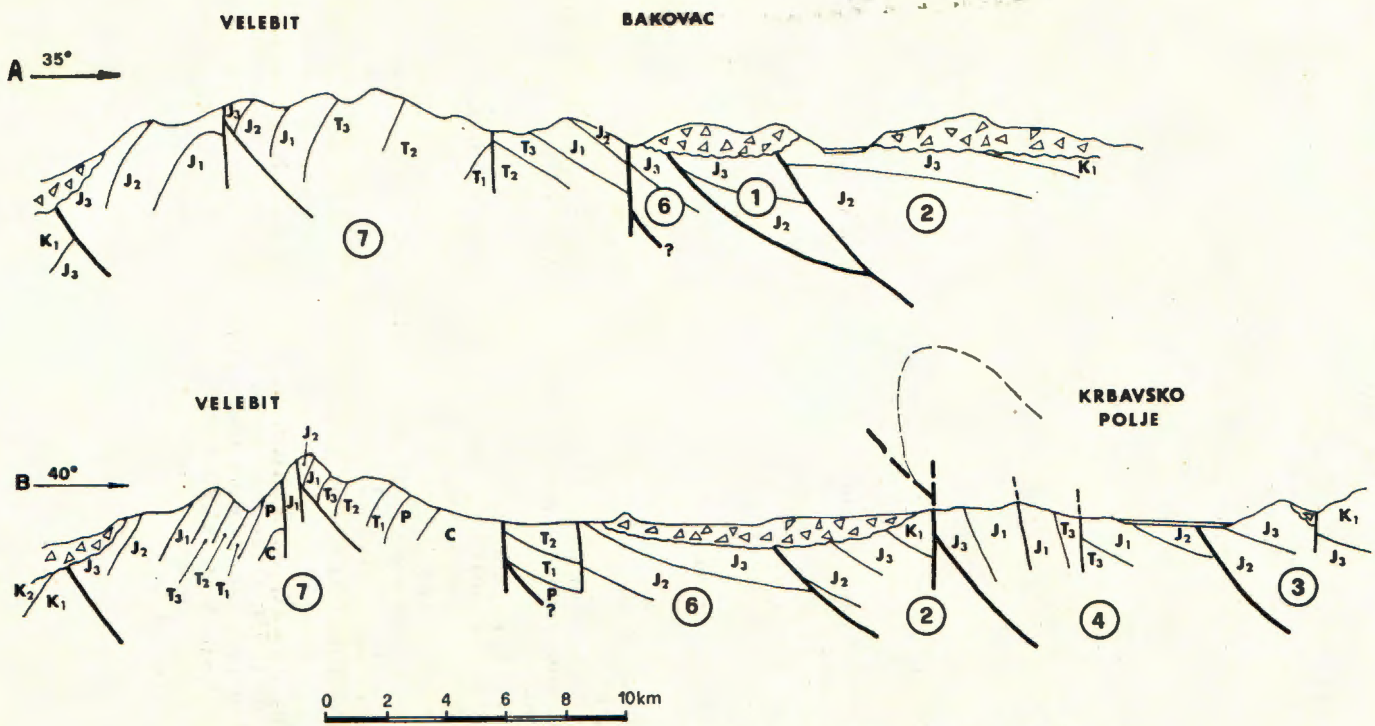


Fig. 3. Sample of Jelar breccias S. E. of Gospić showing incorporation of the light breccia consisting of Upper Cretaceous fragments (a) into the dark one which is composed of Jurassic and Lower Cretaceous components (b). It testifies that the age of fragments may not be relevant for the age of the breccia itself.

Sl. 3. Uzorak Jelar-naslaga jugoistočno od Gospića u kojem je svjetlija breča (a) uključena u tamniju (b) iako se ona sastoji od gornjokrednih a tamnija od jurskih i donjokrednih fragmenata; vidi se da starost fragmenata ne mora biti mjerodavna za starost breče.



Text-fig. 4. Possible structural relations within the area of the fig. 1.
Sl. 4. Mogući strukturni odnosi u području sl. 1.

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Uloga vapnenačkih breča (Jelar formacija) u tektonskoj interpretaciji Zone visokog krša u Dinaridima

M. Herak i *S. Bahun*

UVOD

Vapnenačke breče s nešto konglomeratičnih komponenata u području Like i Velebita predstavljaju litostratigrafsku jedinicu debelu mjestimično i preko 300 m, za koju se dugo vremena držalo da pripada srednjem dijelu krede i da leži diskordantno na jurskim vapnencima i dolomitima.

Detaljnija istraživanja u posljednja dva desetljeća u vezi s izradom Osnovne geološke karte SFRJ kao i u okviru brojnih praktičnih radova, pokazala su da njihov veliki dio pripada paleogenu. Ujedno su pronalažena nova područja breča i proširivan je njihov stratigrafski raspon, pa su pribrajane različitim nivoima od srednje jure do paleogena (izuzetno čak i do neogena). Paleogenski dio najčešće je smatran ekvivalentom Promina-naslaga. Samo je Bahun (1963) predložio da ih se posebno tretira pod imenom Jelar-naslage zbog razlika u sastavu i nedostatku dokaza za njihovo vremensko podudaranje s Promina-naslagama.

I postanak im je bio različito objašnjavan, osobito onim zonama koje su pribrajane mezozojskim sistemima. One su smatrane (a) kao vremenski ekvivalenti evaporitnih sekvenci (Šušnjar et al. 1965), (b) kao rezultat lokalnih ili regionalnih poremećaja koji su se ponavljali (Osnovna geološka karta) i (c) kao posljedica geotektonskih poremećaja vezanih uz »transverzalu Split—Karlovac« (Chorowicz 1977).

Potreba preispitivanja dokumentacije pojedinih koncepcija u više se navrata nametala, a objavljeni listovi Osnovne geološke karte olakšali su postupak jer sadrže veoma detaljno raščlanjene litostratigrafske jedinice s jasnim upućivanjem na neriješene probleme. To je u velikoj mjeri olakšalo terenski posao u svrhu provjere i dopune izravnih zapažanja.

RASPROSTRANJENOST BREČA

Ivanović et al. (1967) i Chorowicz (1967) spominju breče u srednjoj juri (a i kasnije). S obzirom na to da se one mogu smatrati sinsedimentnima (»monogenetskima«), nema potrebe za njihovo preispitivanje u ovoj prilici.

Pravi problem predstavljaju heterogenetske (»poligenetske«) breče koje se sastoje od komponenata različite starosti u rasponu od trijasa do paleogena, a rasprostranjene su u više zona (sl. 1).

Blizu kontakta s navlačnom jedinicom Udbine prevladavaju trijaske komponente, u području između Lovinca i spomenute navlačne jedinice jurske, a u brečama unutar krede jurski i kredni fragmenti. U mnogim dijelovima breča nalazimo jurske, kredne (uglavnom gornjokredne) i paleogenske sastojke, a ima ih na trijaskim i krednim terenima. Razlike u sastavu i prividno uska povezanost s vapnencima i dolomitima različite starosti bili su razlogom da su i breče pribrajane gornjoj juri, baremu, donjoj kredi (uopće), alb-cenomanu, paleogenu i prelazu paleogen—neogen. Kontakti su najčešće pretpostavljeni kao diskordantni, čak i među pojedinim kompleksima breča (gornja jura—donja kreda, donja kreda—paleogen), što bi pretpostavljalo intenzivne strukturne poremećaje na relativno ograničenim prostorima, kao i emerziju između taloženja pojedinih kompleksa breča. To je nametnulo potrebu novog pristupa objašnjenju postanka breča i njihove uloge u tektonici.

POSTANAK BREČA

S obzirom na to da heterogenetske breče sadrže fragmente različite starosti, od donjeg trijasa do paleogena, jasno je da to pretpostavlja ne samo eroziju do donjeg trijasa nego i značajnije tektonske poremećaje koji su omogućili tako duboku eroziju. Ti poremećaji nisu mogli vremenski varirati od mjesta do mjesta i ujedno u nekim područjima trajati od gornje jure do neogena, kao što bi trebalo pretpostaviti u slučaju superpozicije heterogenetskih breča različite starosti. A tako kompleksna varijabilnost na širem prostoru bila bi u suprotnosti s relativno kontinuiranim sekvencama vapnenca i dolomita u graničnim područjima s brečama. Pa i u slučaju stratigrafskih praznina podinska i krovinska sekvenca su više ili manje konkordantne, tako da se može pomišljati samo na epirogenetske pokrete bez bitnih strukturnih promjena, pa prema tome i bez mogućnosti stvaranja heterogenskih breča.

S obzirom na to da su odnosi breča s vapnencima i dolomitima mezozoika najčešće nejasni, što vrijedi i za međusobni odnos pojedinih kompleksa breča, a fosili u fragmentima mogu poslužiti samo za određivanje moguće gornje starosne granice, ništa ne stoji na putu da se heterogenetske breče smatraju litostratigrafskom cjelinom kojoj je postanak vezan uz jednu orogenezu (s više faza). S obzirom na to da su na mnogim nalazištima određeni i paleogenski fragmenti, starost breča ne bi mogla biti veća od paleogena. A tome u prilog govore i druge indikacije.

Stratigrafske praznine (mjestimično trajna emerzija), kao i slaktovodni odnosno brakični »liburnijski facijes« na početku paleogena, govore za jače promjene u okviru laramijskog boranja. S tim je povezana i relativna ograničenost paleogenskih marinskih naslaga (vapnenaca i fliša) na uzdužne pojaseve s ograničenim vezama posredstvom spojenih kanala. Produbljivanje sedimentacijskog prostora indicirano je horizontalnom ekspanzijom fliških sedimenata u usporedbi s podinskim vapnencima. Te se promjene nisu mogle odigrati bez strukturnih poremećaja (boranja, pucanja i drobljenja) izronjenih mezozojskih karbonatnih terena koji su poslužili kao ishodište karbonatnih komponenata fliša, dok su jezgre antiformi, u koliko su bile otvorene, omogućile pretaloživanje siltnih i glinovitih čestica. A da bi došlo do tako duboke erozije, antiforme su morale biti raspucale, pa su istovremeno omogućile blisko pretaloživanje većih vapnenačkih fragmenata. Pritom je usko područje između flišnog bazena u Ravnim Kotarima i glavne mase vapnenačko-dolomitnih terena ostalo bez kontinuiranog pokrivača, pa su tu formirana boksitna ležišta (sl. 2). Završetak sedimentacije fliša u današnjem primorskom pojasu bio je obilježen snažnijim tektonskim poremećajima. Tako je i fliš boran i lagano naljuskan zajedno s vapnencima u podlozi. Mezozojski karbonatni tereni visokokrške zone bili su u to isto vrijeme podvrgnuti jakim tangencijalnim poremećajima. Tako su mnoge bore prebačene prema jugozapadu. Diferencijalni potisak izazvao je i rasjede različitog pružanja i intenziteta, među njima i rotacione, što je omogućilo razlike u premještanju pojedinih tako omeđenih kompleksa, pa je došlo i do navlačenja dekolmanskog tipa na terene različite starosti. Pritom su odvajani i veći ili manji fragmenti svih otvorenih listostratigrafskih jedinica. S obzirom na lakši trasport (uglavnom gravitacijom), oni su taloženi i na dosta udaljene terene od mjesta njihova odvajanja. Osim toga, na čelima navlačnih jedinica dolazilo je do odronjavanja većih kompleksa koji su mogli zadržati i primarnu slojevitost, što je dosad izazivalo znatne poteškoće u interpretaciji. Sporadično se moglo dogoditi da fragmenti mlađih naslaga budu taloženi prije starijih, pa zato ponekad izgleda da su gornjokredni fragmenti pokriveni donjokrednim i jurskim. Na taj se način mogu objasniti neki slučajevi gdje izgleda kao da breče s paleogenskim ulomcima leže ispod onih koje su bile pribrojene mezozoiku. To ujedno objašnjava zašto su trijaski i jurski fragmenti najčešće u blizini čela navlaka ili jezgara erodiranih antiformi od kojih potječu. Glavne orogenetske promjene dogodile su se najvjerojatnije u gornjem eocenu, što je omogućilo pojačano nakupljanje i pretaloživanje karbonatnih fragmenata u području visokokrške zone odakle je pritjecao i karbonatni konglomeratični materijal Promina-naslaga koje su taložene diskordantno na fliš, eocenske vapnence, gornjokredne vapnence i boksit.

Ovakva koncepcija postanka heterogenetskih vapnenačkih breča govori u prilog razlikovanju Promina-naslaga koje imaju karakteristike molase i Jelar-naslaga s obilježjima vildfliša (Wildflysch). Jedan od mogućih prigovora koncepciji mogao bi se odnositi na činjenicu da su heterogenetske breče na nekim mjestima jako usko povezane s homogenetskim brečama i s nekim jurskim i krednim vapnencima što daje dojam o njihovoj genetskoj povezanosti. Na to bi se moglo odgovoriti da su u tim slučajevima breče taložene na terene koji su već bili tektonski poremećeni s izdancima različite starosti u okviru kojih su mogle biti i homogenetske breče. Prema tome lako je razumjeti da su i podinski tereni breča pri tektonskim poremećajima raspucali i ispunjeni zdrobljenim materijalom različite starosti.

Na analogan se način mogu objasniti slučajevi gdje jurski ili kredni vapnenci prividno postupno prelaze u heterogenetske breče koje sadrže gornjokredne i eocenske fragmente kao dokaz njihove paleogenske starosti. Za primjer može poslužiti nalazište blizu Baških Oštarija, gdje prividno postoji kontinuitet od gornje jure (vapnenci s *Clypeina jurassica*), preko homogenetskih breča do heterogenetskih breča koje sadrže kredne fragmente, pa je očito da se radi o diskontinuitetu. U smislu naše koncepcije lako se objasne i slučajevi gdje stariji fragmenti ispunjavaju pukotine mlađih heterogenetskih (šarenih) breča, ili gdje su mlađe breče sastavni dio breča koje se sastoje od jurskih fragmenata, što isključuje njihovu jursku starost (sl. 3).

ZAKLJUČCI

Heterogenetske breče s nešto konglomeratične komponente, koje su dosad pribrajane različitim horizontima od srednje jure do neogena, produkti su orogenetskih poremećaja kombiniranih s erozijom. Sve su one tercijarne (uglavnom paleogenske) starosti, a vremenski su ekvivalenti ne samo molasnih Promina-naslaga Ravnih Kotara, nego i većeg dijela fliša.

Predloženi model njihova postanka i njihovo više ili manje koatično pojavljivanje, s dosta urušenih elemenata, govori u prilog shvaćanju da su one analogne vildflišu prije nego molasi.

Ovakvo shvaćanje olakšava stratigrafsku korelaciju s terenima na kojima nema breča. A lakše je razumjeti i pojavu manjih površina breča bez jasnih rasjeda u području gornjokrednih sinformi.

Tercijarna starost breča omogućuje pretpostavljanje produživanja glavnih tektonskih poremećaja i ispod njih, što olakšava rekonstrukciju različitih tektonskih jedinica koje su dosad ostale nejasne (sl. 1). Time je promijenjeno shvaćanje strukturnih odnosa (sl. 4), što zahtijeva preispitivanje, s potvrdom ili promjenom i u susjednim područjima.

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