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Izvorni znanstveni članak

MORPHOLOGICAL AND GEOLOGICAL INDICATORS OF THE POSSIBLE BAUXITE DEPOSITS IN THE KARST REGION OF WESTERN HERZEGOVINA

Ivan BLAŠKOVIĆ, Ivan DRAGIČEVIĆ and Josip TIŠLJAR

Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia

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Investigation results of morphological and geological potential bauxite deposit indicators in the Mesihovina-Rakitno bauxitebearing sedimentary basin in Western Herzegovina are presented. Region with carbonate and clastic hangingwalls as well as those without overlying sediments have been studied. It was established that the expression and number of the indicators depend size as well as on character and thickness of hangingwall sediments. The morphological indicators are expressed as a particular relief forms situated right above the deposits or nearby and are a consequence of geological relations and exodynamic processes. The numerous geological indicators resulted from complex geological events. The most important are: preore structural relations, the formation of paleorelief, peculiar way of hangingwall rocks sedimentation, lithification processes and the formation of the recent structural pattern. It has been observed that particular indicators sould be recognized within a relatively thick succession of the overlying sediments which is of the great importance in the exploration of bauxite deposits.

Ključne riječi: Ležište boksita, Morfološki pokazatelji, Zapadna Hercegovina

U radu su prikazani rezultati istraživanja morfoloških i geoloških pokazatelja mogućih ležišta boksita u boksitonosnom sedimentacijskom bazenu Mesihovina-Rakitno. Proučavana su područja s karbonatom i klastičnom krovinom, te predjeli bez krovinskih naslaga. Ustanovljeno je da izraz i brojnost pokazatelja ovisi o veličini ležišta, te debljini i karakteru krovinskih sedimenta. Morfološki pokazatelji očituju se kao specifični oblici iznad ležišta boksita ili u njihovoj blizini. Uočeno je da su oni rezultat geoloških odnosa i egzodinamskih procesa. Brojni geološki pokazatelji su rezultat kompleksnih geoloških zbivanja. Najvažniji su: predrudni strukturni odnosi, formiranje paleoreljefa, specifičan način sedimentacije krovinskih naslga, procesi litifikacije i formiranje recentnog strukturnog sklopa. Uočeno je da je pojedine od pokazatelja moguće prepoznati u relativno debelom slijedu krovine što im daje i veliko praktično značenje.

Introduction

By intensive researche on revealing geological conditions of bauxite formation in the karst region of Western Hercegovina, the existence of certain surface indicators as signs for a possible occurence of bauxite deposits was discovered. These indicators are of geological and geomorphological kind and will be presented here in a sequence of logical continuation of their formation processes. The ore-forming process, i.e. the origin of source material and its transformation into bauxite will be omitted.

The prore and postore tectonic processes as well as implied paleogeomorphological conditions will be considered. The depositional of hangingwall rocks and subsequent diagenetic and exodynamic processes are studied and interpreted.

Detailed investigations have been done on uncovered bauxite deposits and then on those established by exploration drilling using a geological map 1:5000 as wel as aerial photos and field drawings. A very carefull geomorphological and geological reconnaissance of particularly interesting localities have been done, too.

The explorations have been concentrated on the Paleogene bauxite bearing basin Mesihovina-Rakitno, in between Tomislavgrad and Posušje in the area of Studena Vrila and Oluja on the west and Sutina and Konjovac on the east (Fig. 1).

Geological setting of the explored area

The explored area consists of carbonate, mostly calcareous Upper Cretaceous rocks and Paleogene limestones and clastics. The Upper Cretaceous limestones are the bauxite footwall. By the Laramian orogenic events at the end of Cretaceous period these rocks were folded and a continental regime was established. Simultaneously, within folded anticlinal structures open joint systems formed (B l a š k o v i ć & D r a g i č e v i ć, 1991). In this phase of consequent relief the karstification and moulding of open joints and fissures were very intensive. In these joints and fissures the source bauxite material (parent rock) accumulated.

By the Upper Paleocene-Lower Eocene transgression all large land masses were gradually flooded. As a consequence, the Upper Cretaceous paleorelief is discordantly overlied by Paleogene limestones and clastics. The latter are bauxite hangingwall rocks.

The bauxite footwall i.e. the Upper Cretaceous rocks, are represented mostly by shallow marine limestones of Turonian-Senonian chronostratigraphic range. Sporadicaly, these limestones contain very abundant rudist associations. Chiefly, the beds consist of rudist debris and various fossil fragments (coquinas, microcoquinas, coquinites). The limestone bedding planes are not well-marked (R a d i ć et al., 1978).

The morphological expression of these rocks is heterogeneous. In parts with insignificant tectonic relief it is characterized by gentle, uniform elevated forms, slopes and valleys. The ground is mostly flat without cropping out blocks or limestone beds. It is covered with irregular slab-like limestone fragments which mask true strike and dip of beds. The valleys

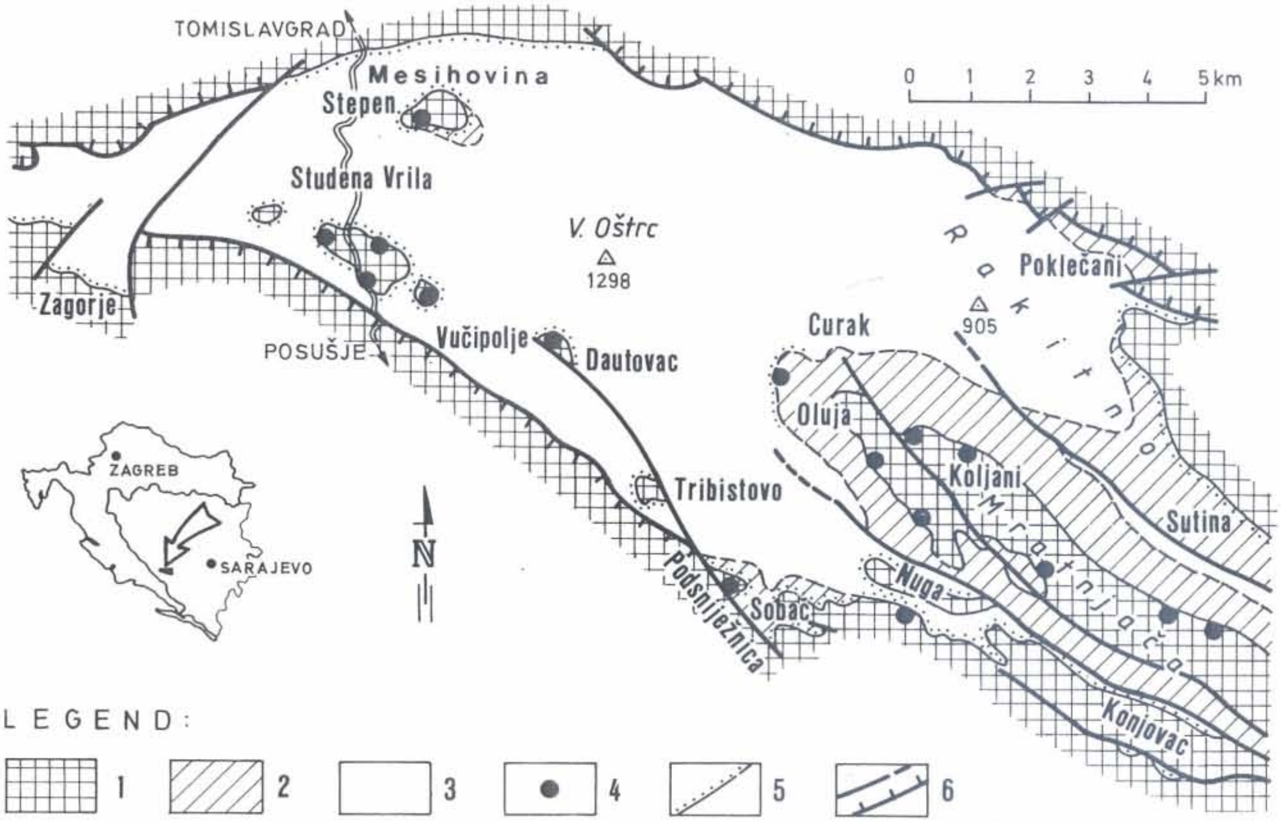


Fig. 1. Simplified geological map of the investigated area. (Based on data from Geologic map, Sheet Imotski)
1- Turonian-Senonian limestones (bauxite footwall) **2**- Eocene foraminifera limestones (bauxite hangingwall) **3**- Eocene Promina formation (bauxite hangingwall) **4**- Bauxite deposits **5**- unconformity **6**- faults

are characterized by linear arrangement (strike) which points to tectonic predisposition. In cross sections they resemble to a wide but noticeable "V" letter. The large number of valleys begins with a circular, flattened form having a shape similar to dolinas ground surface contour.

In parts with intensive tectonics, faults, reversed faults and overturned fold hinges the relief forms are more heterogeneous and indented. Chiefly, they are marked bu the cropping out of huge limestone blocks with abrupt slope changes, with well developed karrs, numerous joint systems and pronounced petterns of karstification.

As the most expressive karst form, dolinas are very abundant in this area giving the pattern of chaotic arrangement. Mosty, they are not completely opened but filled with bauxite or terra rossa, as well with a limestone fragments. They are flattened and only by a circular surface contour of some tens of meters diameter remind to well known typical karst forms.

The morphology and recess arrangement in bauxite footwall paleorelief

The recesses in the footwall paleorelief are genetically connected with opening of joints in mostly smooth anticline structures. These joint systems originate in the Laramian phase at the end of Cretaceous. They could be classified into 3 different types (B l a š k o v i ć & D r a g i č e v i ć, 1991):

a) Recesses predominantly formed by the opening of tension and shear joints the II. order (congruently with fold axis). They are seated within the narrow elongated zone parallel to anticline axis which is over 200 m long.

b) Recesses formed by the oppenig of system of joints of the I. and the II. order. These are seated within the wider zone of anticlinal axis mostly. Their ground-plan contour is polygonal of roughly equal width and dimensions of 20 to 40 meters.

c) Recesses formed by predominantly shear joints of the I. order (normal and diagonal to the anticline axis). These are seated within the anticline limbs, particularly within the part which shows a trend of an eshalon horizontal bending. They have elongated shape with length over 100 m and width up to 40 m.

The primary shape of those three types is characterized by very steep almost perpendicular wall-sides, by narrowing in lower part and roughly flattened or funneled bottom. By exodynamic process the primary straight forms are partly smoothed. It was particulary effective on the edges so the upper parts of recesses become funnel shaped.

The bauxite material accumulation

In the recesses formed during the emersion phase which is of undefined exact time duration, the prime bauxite material was accumulated. Without considering the origin of this material, its transport and deposition we can stress by a few facts observed by the fieldwork. The bauxite material fills the recesses approximately up to the half of their volume or less. The funnel shaped upper parts remain unfilled.

Mostly, these forms are observed within deposits with noneroded preserved hangingwall rocks. In regions with eroded hangingwall rocks the upper funnel shaped part could be destroyed up to the level filled with bauxite or frequently even the whole potential deposits could be completely eroded (Fig. 2).

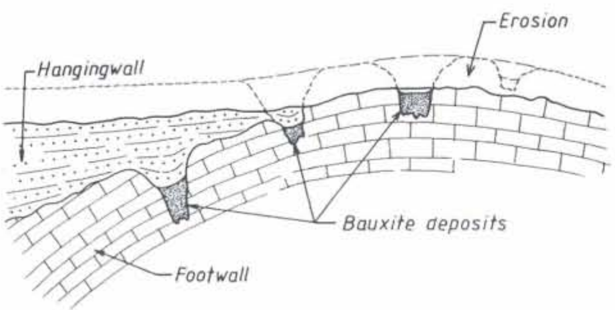


Fig. 2. Schematical illustration of preserved and partly or completely eroded bauxite deposits (not in scale)

The deposits hangingwall

As now is generally accepted, by gradual Upper Paleocene and Lower Eocene transgression the deposition of the hangingwall strata started. There were different depositional regimes with emphasized dynamics of different land masses surrounding the basin. As the result one can distinguish two different forms of hangingwall Paleogene strata. One is Promina clastic formation and the other carbonate foraminifera limestones formation (D r a g i č e v i ć et al., 1992).

PROMINA FORMATION

In the area of Studena Vrila this formation consists of two basic lithological members which are vertically and laterally interbedded. One is represented by finegrained clastics, sandy and silty marls and other bu conglomerates of mostly limestone pebbles in sandy matrix (Fig. 3).

The deposition of Promina formation in every investigated locality starts with finegrained clastics. In the basis of the sequence they are up to 150 m thick, and shallower parts, which correspond to anticlinal parts of paleorelief structures mostly, as the result of intrabasin transport and dynamics, the finegrained clastics become more and more thinner

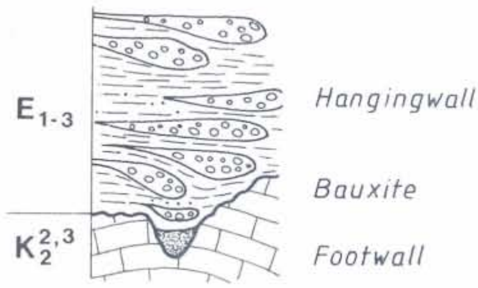


Fig. 3. General lithological column of bauxite deposit overlain by Promina formation clastics (not in scale); Hangingwall: Eocene Promina Formation, alternation of the sandy marls and conglomerate lenses; Footwal: Túronian-Senonian limestones

or disappear; the footwall rocks are directly overlain by limestone conglomerates. However, in open fissures with bauxitic material, almost as a rule, bauxite is overlain by finegrained basal member of Promina formation of variable thickness depending on recesse's depth and area.

Sedimentation was characterized by periodical alteration from (1) quiet supply of finegrained clastic material and its relatively uniform distribution within the basin, and (2) short-lived, erratic abrupt flows of coarsegrained clastics with progradational sedimentary pattern (D r a g i č e v i ć et al., 1986). The importance of such rapid flows lies in submarine erosion of previously accumulated finegrained

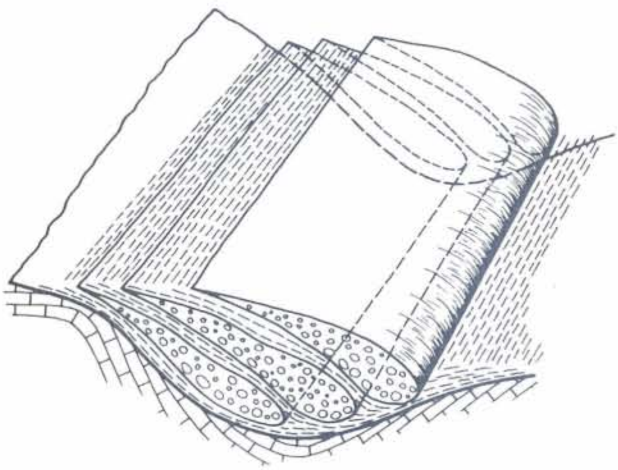


Fig. 4. Schematical illustration of regularly prograding disposition of conglomerate lenses in a case of uniform bottom morphology of sedimentary basin (D r a g i č e v i ć et al., 1986)

clastics on updomed basin parts and their redistribution within the basin. With the deposition from such a rapid, relatively short flow, lenses of different shape and thickness are formed. Wthin the basin with uniform bottom morphology these lenses are wide spread, relatively normally interbedded, having uniform thickness and forms with smooth unsharped front and with gradualy thinner tail (Fig. 4).

In parts of the basin with indented, recesse marked bottom relief, although of small size and filled with bauxite, the coarse grained flow gravitated toward them and they served as sediment distribution channels. Lenses of variable shape conformably to the size and shape of recesses were formed. Particularly thick, unsharp fronted and rapid thinned short tailed small bodies of coarse grained clastics having erosional channel patterns are incorporated within a finegrained sediment (Fig. 5).

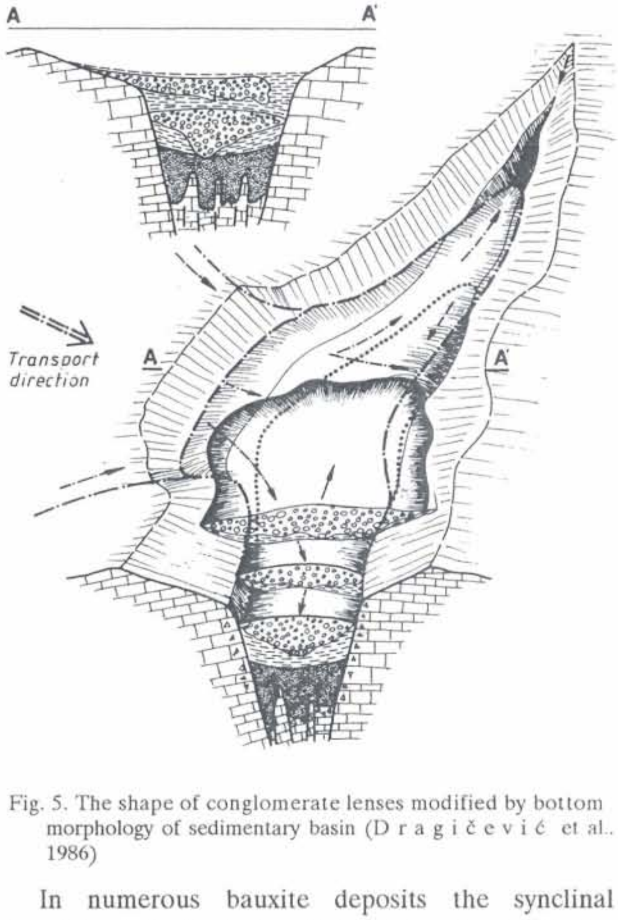


Fig. 5. The shape of conglomerate lenses modified by bottom morphology of sedimentary basin (D r a g i č e v i ć et al., 1986)

In numerous bauxite deposits the synclinal bending of beds - lenses of hanging-wall strata, i.e. collapse structures were observed. These structures occur as a consequence of recesse shape and subsequent tectonic changes as well as by compaction and lithification of bauxite material and overlying sediments which reduce their volume (Fig. 6).

The recent morphology of litho members is variable. Parts of the territory consisting of finegrained clastics exhibit a relief moderate forms covered by vegetation. The limestone conglomerate lenses are well expressed in relief as steplike forms of clear strike and width, mostly without vegetation cover.

The outcrop of conglomerate lenses in cases of their regular interchange regardless of terrain morphology is easily recognisable (Fig. 7).

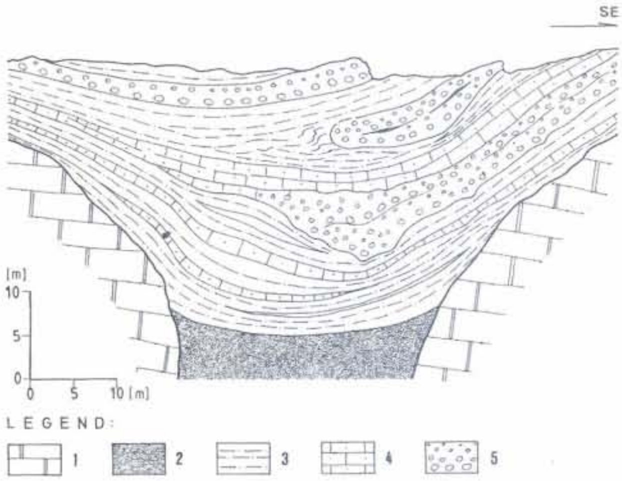


Fig. 6. Synclinal bending-collapse structure in Promina formation hanging-wall rocks. Field sketch.
1- Turonian-Senonian limestones **2**- bauxite **3**- silty marls **4**- calcarenite **5**- conglomerate

In parts where lenses are deposited in indented basin bottom conditions their outcrops shows chaotic arrangement of strike, dip and thickness (Fig. 8).

In case of such a chaotic arrangement, it is possible,

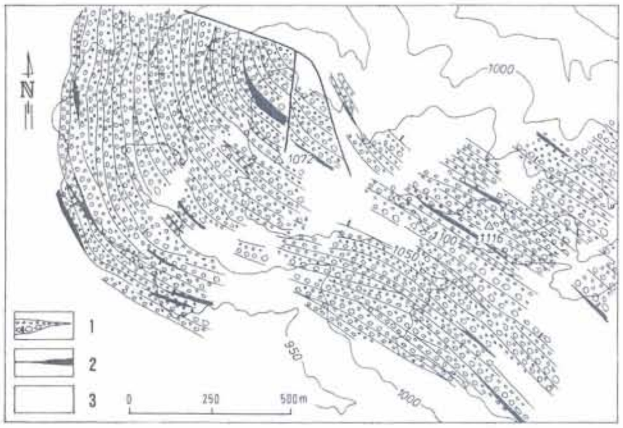


Fig. 7. Regular arrangement of Promina formation conglomerate lenses. Photogeological sketch.
1- conglomerate lenses with direction of dip **2**- sandy marls beds or lenses **3**- covered area.

by photogeologic reconnaissance, to make an uncorrect interpretation of structural relations by considering this completely sedimentary structure as indicators of folding and faulting.

Within the rock of the Promina formation, where conglomerate lenses predominate, the definition of beds strike and dip demand certain correction. The specific shape of conglomerate lenses which obey the basin bottom configuration and with marked cross lamination textures indicates that neither upper nor lower bed plane represents the real bed orientation. This orientation could be more correctly determined in finegrained clastics interstratified members of greater thickness (of two of more meters).

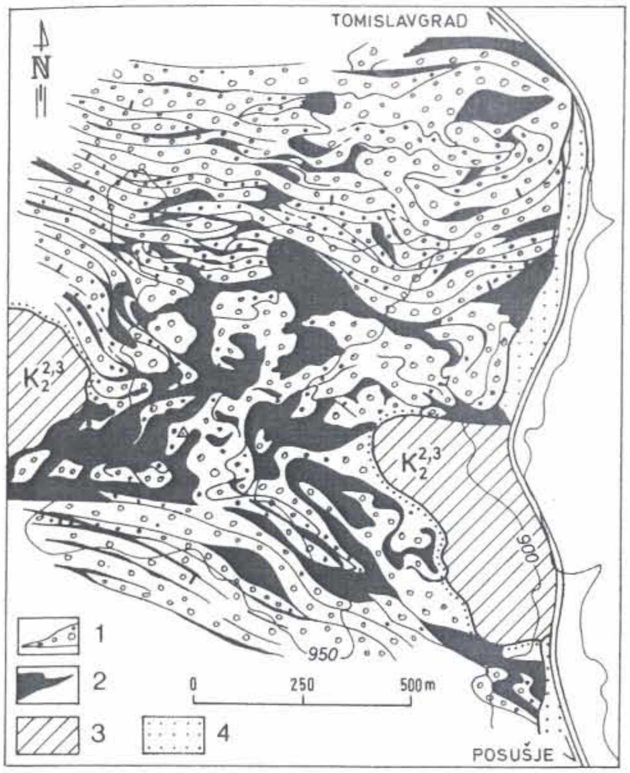


Fig. 8. Irregular arrangement of Promina formation conglomerate lenses. Photogeological sketch.
1- conglomerate lenses with direction of dip **2**- sandy marls beds or lenses **3**- Turonian-Senonian limestones **4**- alluvium

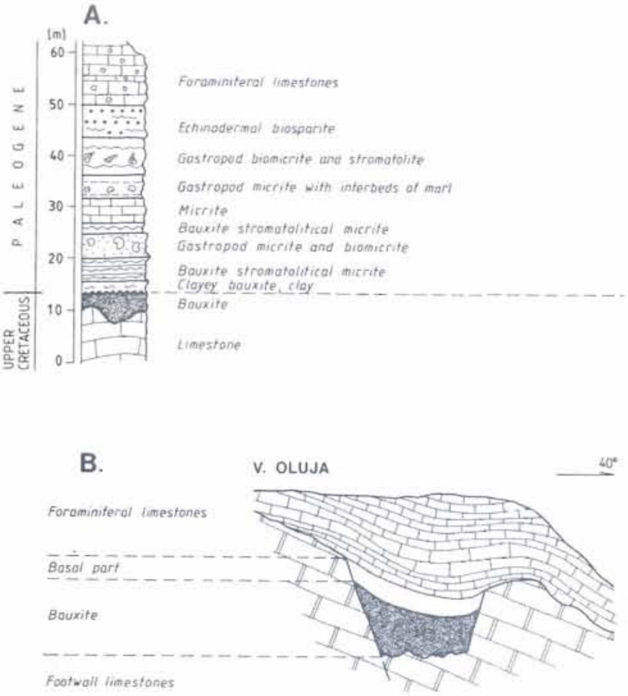


Fig. 9. Lithological column of bauxite deposit overlain by foraminifera limestones (Velika Oluja-Curak cross section)
A- basal part of lithological column **B**- position of basal part of lithological column

THE FORAMINIFERA LIMESTONE FORMATION

Within a part of the Upper Cretaceous paleorelief during the Paleogene transgression and phase of inundation the continental influence was neglected; the deposition of shallow marine to reef limestones predominate. The foraminifera limestones build up the biggest part of the investigated area; reef and perireef limestones appear as their lateral equivalents in a smaller part.

The foraminifera limestones (D r a g i č e v i ć et ai., 1992; R a i ć et al.,1978) are chiefly biomicrites and gastropodal or miliolidal or similar to Kozina beds as well as alveolina or numulitic limestones. They are of the Upper Paleocene-Middle Eocene chronostratigraphic range. The older, basal part of calcareous sequence with miliolids and gastropods as well as the younger part of mostly numulitic limestones, represented by micrites with relatively higher mud ratio, are well thinly bedded (10-20 cm) and with scarsely developed karst relief forms could be compared to alveolina limestones.

The lithological composition and sedimentary patterns of carbonates as a direct bauxite hangingwall show specific characteristics (D r a g i č e v i ć et al., 1992; Fig. 9.). The bauxite hangingwall complex starts with bauxitics red to brown or greyblue clays, sporadicaly silty clays with transition to marls with abundant mollusk remains. It is overlain by stromatolitic micrites and predominantly red-brown or grey gastropodal biomicrites 1 to 1,5 m thick. The latter gradualy alterate into stromatolitic limestones of very variable thickness depending on recesses depth. By complete filling of paleorecesses this limestones alterate to foraminifera limestones. The fossil content of gastropods, chara and ostracods speaks for fresh to brackish water depositional environment. Development of described sequence points to hypothesis that the first sedimentation phase during the transgression could be connected with rising of ground water table in already karstified paleorelief and with the first drowning of recesses (with bauxite) (Fig. 10).

The morphological and geological indicators of possible bauxite deposits

The bauxite deposits are marked on the surface with morphololological and/or geological indicators. These are more or less noticeable on the size of deposit, thickeness and type of hangingwall rocks. However, their observing demands a detailed and directed analysis of relief forms and geological setting. In making conculsions the synthesis of all available data and even impressions is necessary, because every and even the slightest exception from general local geomorphological and geological setting could represent a valuable indication.

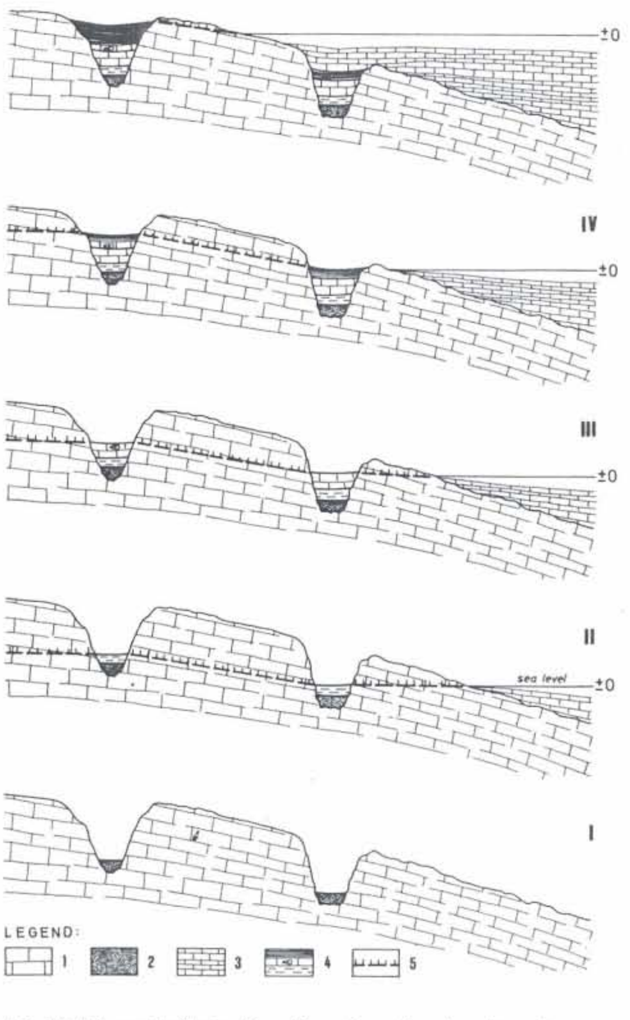


Fig. 10. Schematic illustration of hangingwall carbonate rock development imposed by transgression
1- footwall limestones 2- bauxite 3- foraminifera limestones 4- basal part of foraminifera limestones 5- ground water table

Morphological indicators

The bauxite deposits without hangingwall complex

These occur within of the Turonian-Senonian chronostratigraphic range. Mostly they are more or less degraded by exodynamic factors. As a rule, the upper funnel-shaped part of recesses is destroyed and the lower, narrower part, filled with bauxite, preserved (Fig. 2). Bauxite is covered chiefly with weathered material of surrounding limestones, terra rossa and with bauxite detritus or ooliths. On the ground surface these deposits are funnel-like shaped, with semi-circular flattened opening of dolinas or they show an image of channel type, short dolinas.

On platformed parts of the Upper Cretaceous karst relief without emphasized altidude differences an aboundance of dolinas is usually observed. They are mostly of circular or elipsodial forms with diameters of 10 up to 50 m or more. Many of them are of small depth, having characteristic funnel-like forms with mostly flattened bottom. However, on many places these types of dolinas are almost completely filled ("filled dolinas"); there is only a specific ground surface ring-shaped contour of limestone outcrops which points to their existence. Within this contours there is a flattened, and in comparison with the surrounding grass covered

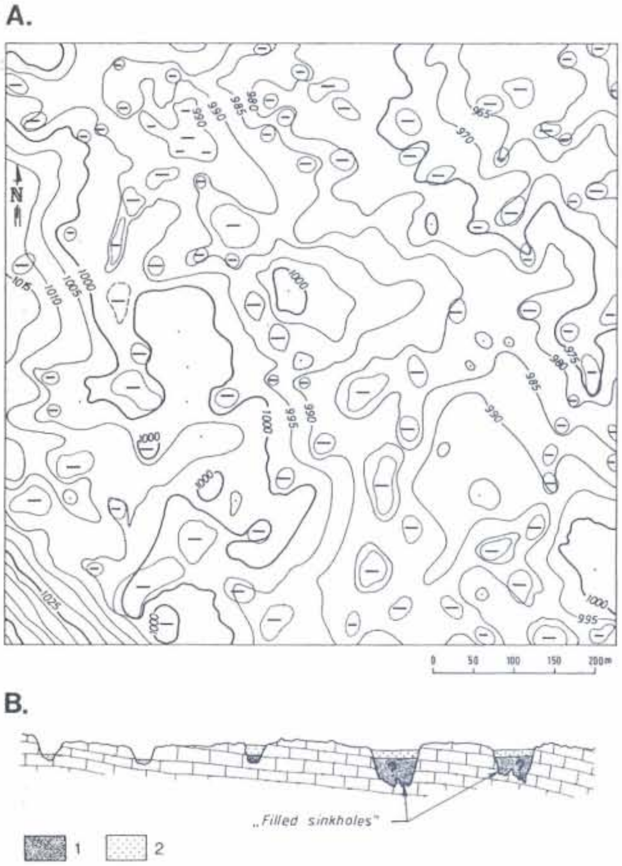


Fig. 11. A- Flattened karst relief with chaotic arrangement of predominantly "filled dolinas" B- The karst relief schematic cross section with dolinas and "filled dolinas" (not in scale). 1- bauxite 2- terra rossa.

terrain of terra rossa, a little bit saged surface. This could be an indicator that beneath a thin cover a possibility of bauxite filled recess exists (Fig. 11).

As all dolinas do not imply the existence of bauxite deposits their value as a deposit indicator should be reexamined. In this case one shoud take into consideration certain structural and tectonic elements. Normaly, the dolinas arrangement, chaotic on the first impression, considered in the scope of structures shows certain regularity. As a consequence of preore tectonics this arrangement could be directed by predominate joint systems in folded structures or by fault zones (Fig. 12).

Already discovered bauxite deposits are exclusively positoned in particular zones of dolinas. They display a trend of grouping on particular ground surface area and along particular directions. Which zones would be bauxite bearing depends on paleogeological conditions. This demands for a detailed investigation

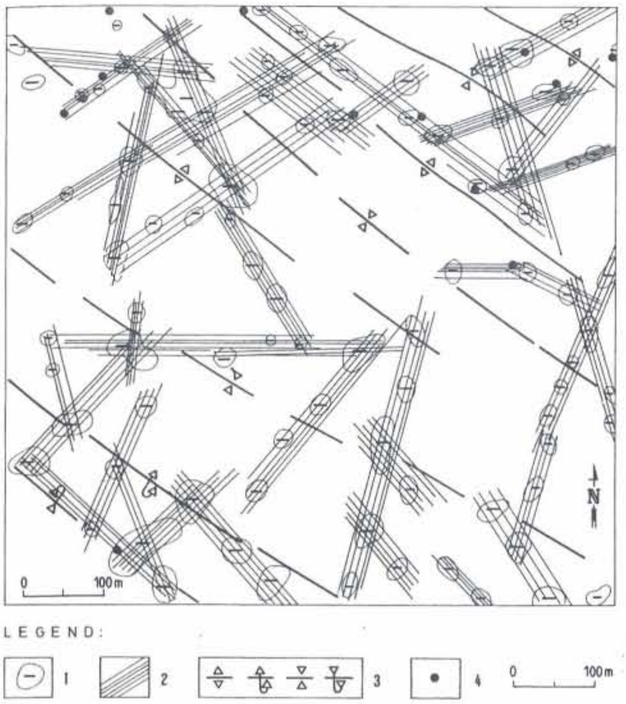


Fig. 12. Disposition of dolinas in expected joint system zones and their relation to folded structure axes
1- dolina **2**- concentration of dolinas along certain directions **3**- upright and overturned anticline and syncline axes **4**- bauxite deposits

on indicated surface. In this circumstances, the dolinas arrangement analysis as indicators of potential bauxite deposits or elimination of areas occupied with sterile blocks deserves adequate attention.

In regions with Upper Createaceous strata on the surface, characterized by a relief of uniformly dipping slopes, the occurence of dolinas is scarce. Mostly these are flattened and grass-rich covered relief parts with diameters of 15 to 40 meters; they represent only a part of so called "filled dolinas" with circular ground surface contour. These are, as a rule, primary forms of valleys (Fig. 13) und could occur repeatedly. Longidudinal section of valley bottom assume a moderate steplike shape.

Described examples of "filled dolinas" and slight discontinuities in mostly uniform carbonate relief represent the bouxite deposit indicators, too, as it was confirmed in the investigated area.

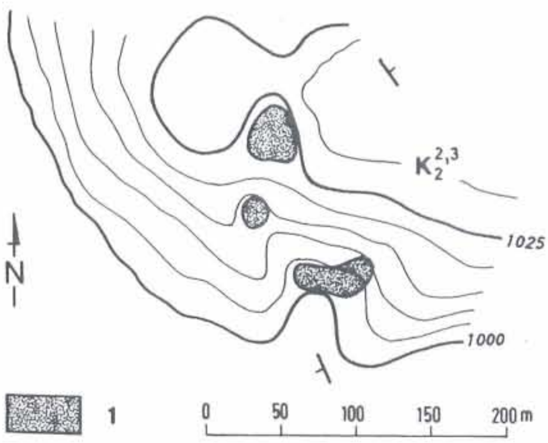


Fig. 13. Morphological indicators of potential bauxite deposits in Turonian-Senonian limestone areas (bauxite footwall)
1- flattened relief parts - filled dolinas - bauxite deposit

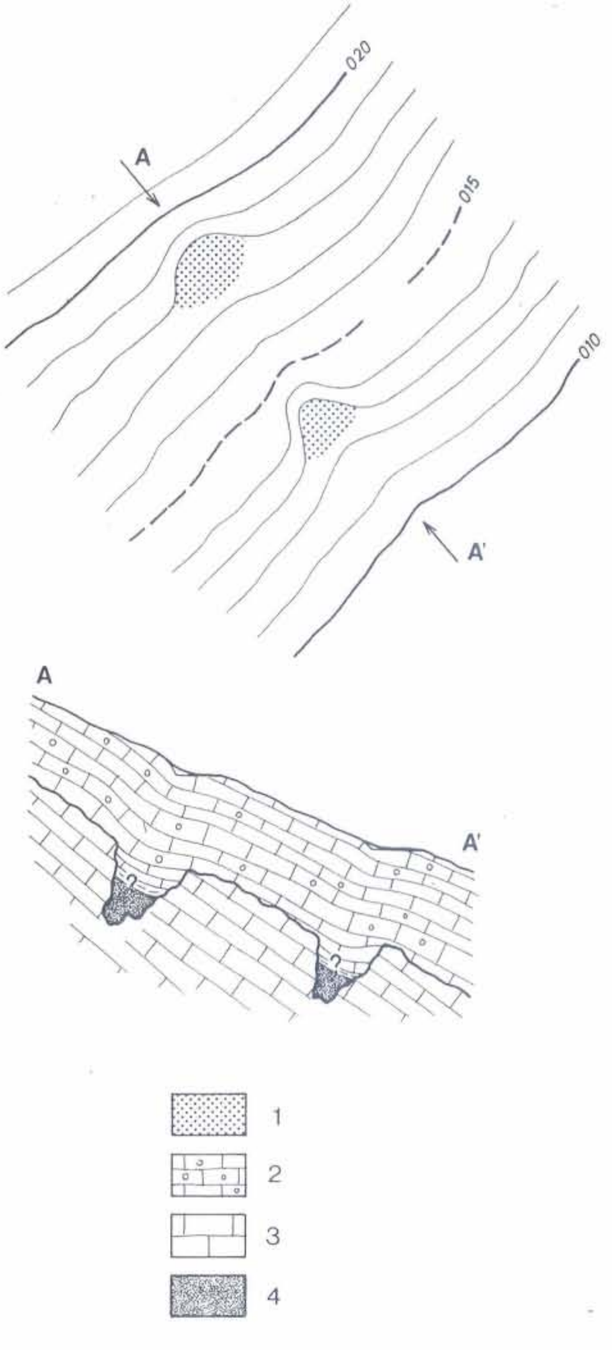


Fig. 14. Morphological indicators of potential bauxite deposit in foraminifera limestone areas (bauxite hangingwall - not in scale)
1- flattened relief parts; ground surface contur of filled dolina **2**- foraminifera limestones **3**- Turonian-Senonian limestones **4**- bauxite

Morphological indicators of covered bauxite deposits

Numerous bauxite deposits are covered by foraminifera limestones or Promina formation clastics. Deposits of chiefly small size are of a relatively slight morphological expression, particularly in cases of thicker hangingwall strata. However, even in these circumstances discrete discontinuities of a relief within particular geomorphological units could be observed. That also are indicators of bauxite deposits. All of this refer to areas of simple tectonic setting.

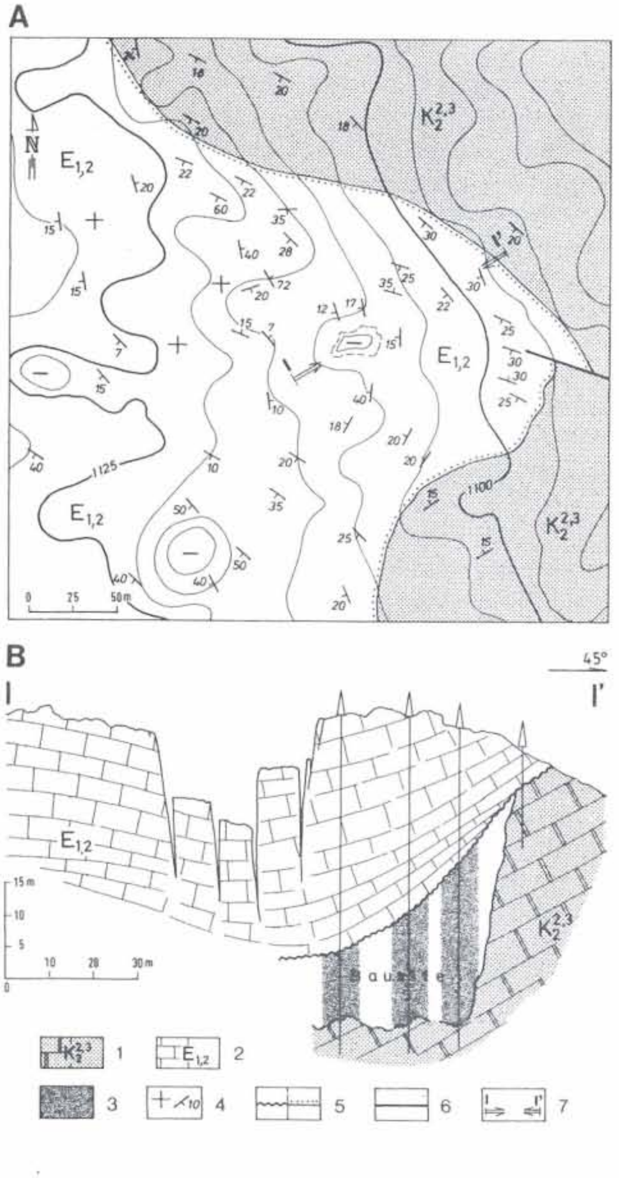


Fig. 15. Morphological and geological indicators of potential bauxite deposits in areas with foraminifera limestones hangingwall rocks

A- Detail from geological map of Jurkanova Lazina with well expressed surface contour of a pit. B- The "pit" geological profile with borehole data.

1- Turonian-Senonian limestones 2- Foraminifera limestones 3- bauxite- 4- bedding strike and dip 5- unconformity 6- fault 7- profile

Foraminifera limestones-bauxite deposits hangingwall rocks

The morphology of areas composed of foraminifera limestones, particulary of alveolina type, resembles to that of the Upper Cretaceous limestones. Here, the dominant karst forms are dolinas, too. They could have a classic funnel-like shape with flat bottom. Feebly expressed steplike parts in longitudinal sections of carbonate relief with grass-rich covered cascades and hardly noticable deviation of dip could also indicate potential deposit existence in small or great depth (Fig. 14). In some morphologically well expressed parts of the soil there are "pits" of circular to chiefly polygonal surface contour with vertical walls and downthrown blocks. Diameters of such pits from 15 to 30 meters or more (Fig. 15). The mentioned manifestations, as confirmed by drilling, could also represent indicators of bauxite occurrences.

Promina formation clastics as bauxite hangingwall rocks

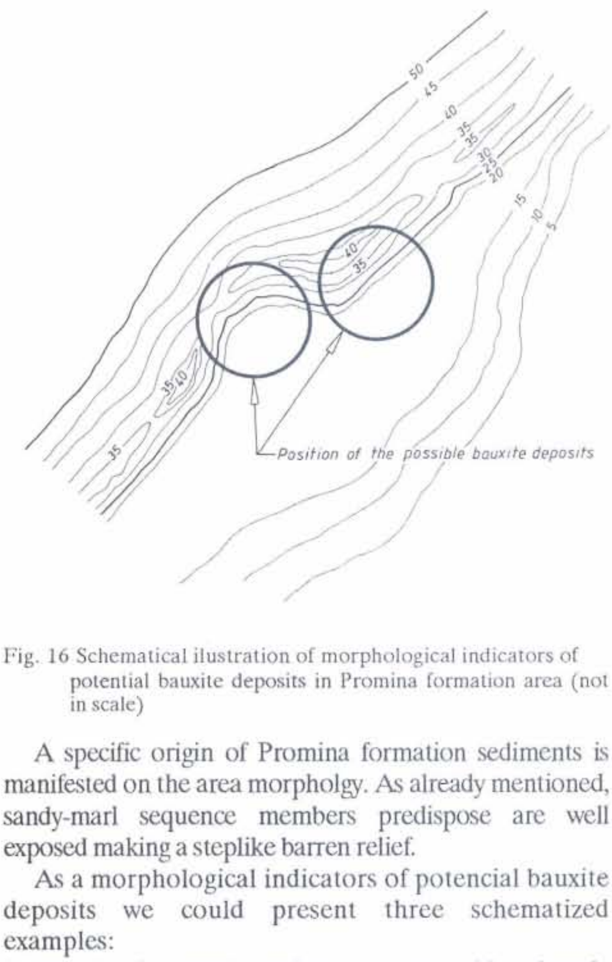


Fig. 16 Schematical ilustration of morphological indicators of potential bauxite deposits in Promina formation area (not in scale)

A specific origin of Promina formation sediments is manifested on the area morpholgy. As already mentioned, sandy-marl sequence members predispose are well exposed making a steplike barren relief.

As a morphological indicators of potencial bauxite deposits we could present three schematized examples:

* mostly flattened region on one side sharply bounded by steep high cascade-ridge of conglomerates of longer strike line. The bauxite deposit is located along this boundary in part of semi-circular concave ridge bend (Fig. 16);

* prominant cascade-conglomerate lense ridge of limited extent but with uniform strike and altitude. Potential bauxite deposit beneath a cascade of this type could be morphologicaly manifested by an abrupt "collapse" of the ridge; above such a deposit there is a rapid decreasing of commonly uniform ridge altitude with well expressed ridge destruction (Fig. 16);
* in flat to bedding congruent areas the appearance of concave-shaped relief forms could be interpreted as an indicator of bauxite deposit even in greater depth (Figs. 15,19,20).

The geological indicators

The bauxite deposits are manifested on a ground surface by numerous more or less noticeable geological phenomena as well.

Depending of size and depth of a deposit and a type of hangingwall rocks the sort and the number of geological indicators will result.

For the interpretation of geological indicators one should start with a detailed and correct geological map as a basis including the clear chronostratigraphic, litostratigraphic and structural- tectonic relations as well. Here, for the exploration of potential bauxite deposits we should start with a hypothesis that every exception from a wellknown geological setting of surrounding area is a potentialy very important geological indicator of deposit existence. Geological data considered as indicators are various - lithological, lithofacial or structural.

Bauxite deposits without hangingwall complex

Regions composed od Upper Cretaceous limestone with bauxite deposits offer relatively scarce geological data which could be considered as indicators. In the first place, amongst all these are bauxite pebbles of fragments mixed within a thin soil cover of flattened relief, in valleys or dolinas. Furthermore, only in close vicinity of a deposit it is possible to find tectonically chrushed and subsequently cemented lime breccia with manganese film. Moreover, tectonically disturbed zones with limestone mylonites could be considered as one of indirect indicators.

Bauxite bearing areas with foraminifera limestone as hanginwall rocks

Depending on the deposition depth and thickness of hangingwall rocks the ground surface geological indicators can be manifested in two ways. One of the undoubtedly reliable indicator of bauxite existence is a particular development of basal part of hangingwall sediments limited exclusively to negative paleorelief.

The second ground surface maniferststion of deposits is clearly structural. It is expressed by collapse structures. These are observed in all coverless deposits with characteristic synclinal bending of the hangingwall strata. The bending is strictly limited to paleorecesses and is vertically

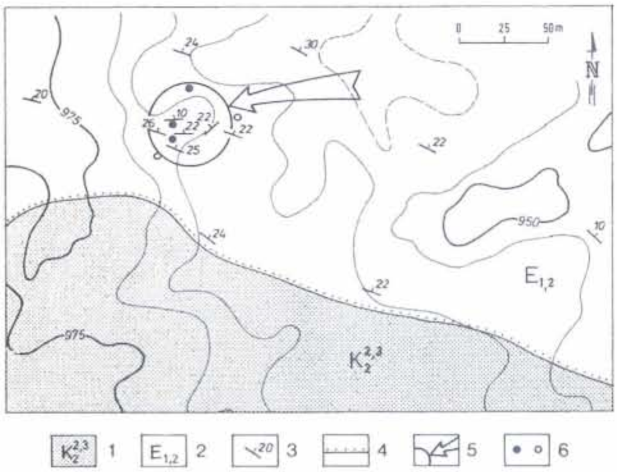


Fig 17. Detail from geological map of Koljani area. Local phenomenon of beds synclinal bending as an indicator of potential bauxite deposit.
1- Turonian-Senonian limestones 2- foraminifera limestones 3- bedding strike and dip 4- unconformity 5- area with synclinal orientation of dips 6- positive and negative boreholes

marked by a very thick succession of the hangingwall complex. Morphological manifestation is more or less noticeable by a moderate synclinal orientation of bed and with mostly consequent morphology (Figs. 15 & 17).

Besides the orientation of bed planes, the joint system arrangement is also in function of collapse structures and represents a very important deposit indicator. The joints are chiefly vertical and of radial pattern located right above a deposit.

Basic surface geological image of collapse structure could be strongly expressed, as well as in

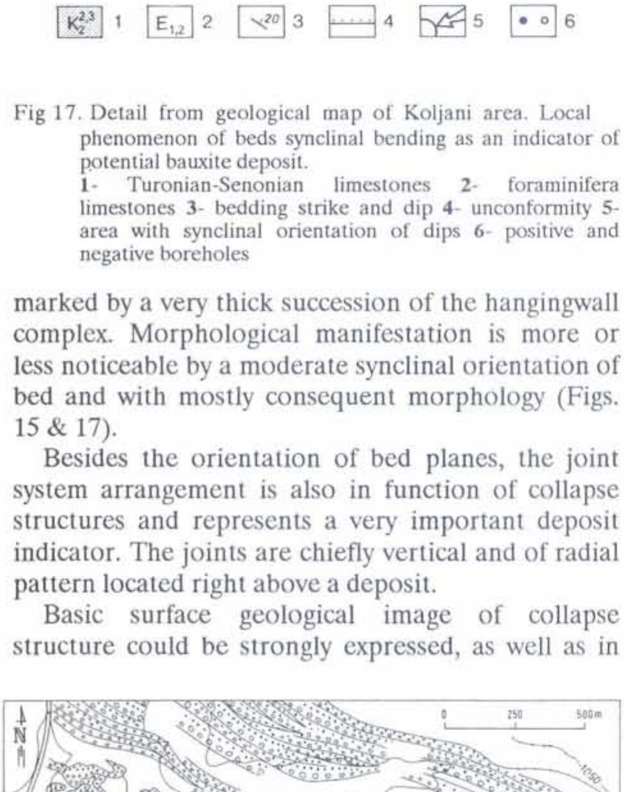
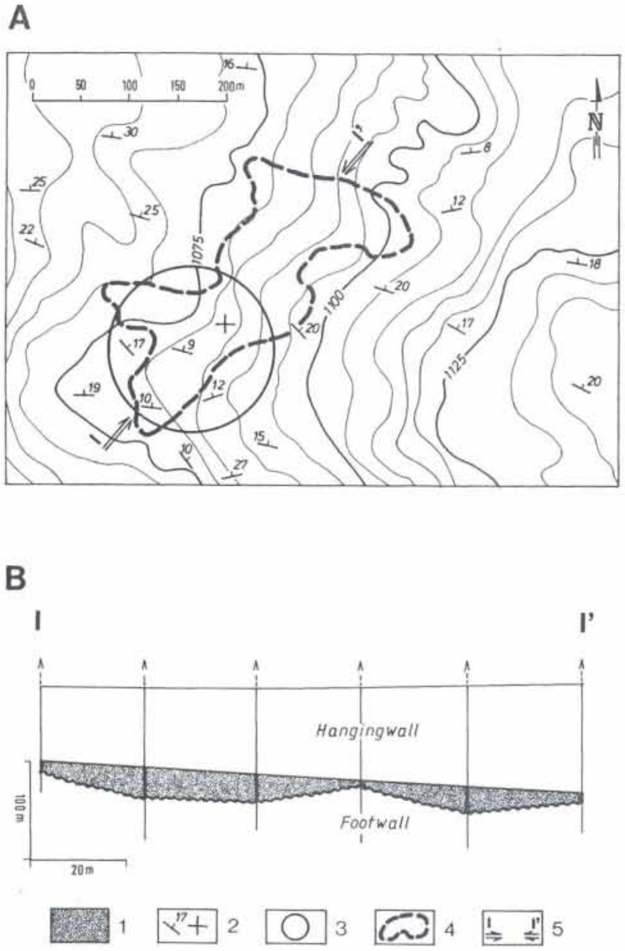


Fig. 18. Photogeological sketch with disposition of different conglomerate lense shapes. "Chaotic" arrangement of lenses as an indicator of potential bauxite deposits
1- Turonian-Senonian limestones 2- Promina formation: a- conglomerate lenses b- sandy marl 3- bed or lense strike and dip 4- unconformity 5- bauxite deposits discovered by drilling



morphological sense, by formation of pits and sink-holes. If this happened the synform orientation of bed planes is slightly expressed in contrast to joint systems and sinking of central limestone blocks. The blocks are bounded by joint systems (Fig. 15).

Promina formation as a hangingwall complex

The following characteristics have been observed in the Promina formation complex:

* directed transport of coarse-grained clastics toward paleorecesses, a recesses distributive function and sediment accumulation (Fig. 5), and
* sin - and postdepositional formation of collapse structures in paleorecess and within hangingwall rocks (Fig. 6).

The basic surface geological pattern of specific Promina formation relief is diversified but recognizable by field observation and particulary by photogeological reconnaissance as well.

One of the first general indication of the Upper Cretaceous limestone paleorelief lies in abundance of well-marked conglomerate lenses of chaotic arrangement and strike. This is strongly emphasized above the very deposits together with a rapid increase in thickness and abrupt wedging out of some conglomerate lenses. Furthermore, some lenses

Fig. 19. A-Detail from geological map of Povaljenica area. Synclinal bending of Promina formation beds with slightly developed concave relief as an indicator of potential bauxite deposit
B- Schematical cross section with borehole data as a confirmation of indicators validity
1- bauxite 2- bedding strike and dip 3- restricted area of synclinal dip orientation of beds and slightly concave relief 4- bauxite deposit contour established by drilling 5- profile

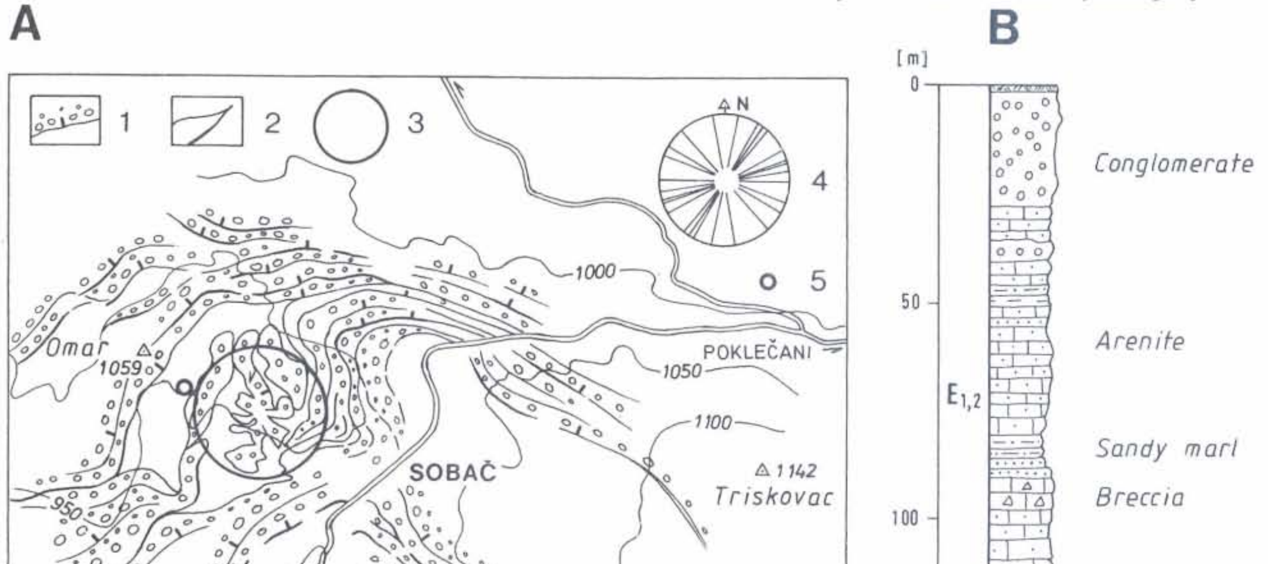


Fig. 20. A- Photogeological sketch of orientation and shape of conglomerate lenses of Promina formation at Sobač area. Synclinal orientation of conglomerate lenses and a "chaotic" arrangement of radial jointed lenses as an indicator of potential bauxite deposits.
B- The borehole lithological column.
1- conglomerate lenses with direction of dip 2- sandy marl 3- restricted area with synclinal orientation of conglomerate lense dips and radial arrangement of joints 4- diagram with joint strikes 5- borehole.

become one conglomerate body by wedging out of sand-marl members (Fig. 18). This phenomena is emphasized by later local and regional tectonics. That is expressed in abrupt changes of lenses strike and dip direction as compared with the surrounding area. Within bauxite zones moderate synclinal orientation of conglomerate lanses predominates (Fig. 19).

Within regions with relatively uniform arrangement of conglomerate lenses the collapse structures in hangingwall rocks are clearly expressed. As in foraminifera limestone hangingwall complexes, the moderate centriclinal orientation of bed planes- lenses are present here as well, together with radial orientation of joint systems directly above a deposit. The thickness of hangingwall rocks in which the mentioned indications as a result of collapse structure have been observed could reach up to 150 m (Fig. 20).

Conclusion

In effort to establish certain geomorfological and geological indicators of potential bauxite existence, in small and great depth, we have been governed by numerous relevant ideas concerning the geomorphological and geological relations of investigated area.

For a geomorphological analysis which takes into account geological relations, as a first step it is necessary to establish certain units of common geomorphological characteristics.

For the geological analysis as well, togethert with detailed geological maps, it is of crucial importance to possess the knowledge of sediment compostion, chronostratigraphic relations. Together with considerable detailed knowledge of tectonic relations and structural characteristics and conditions of bauxite formation as well, it is possible ti distinguish certain geological units of similar geological pattern.

As a rule, by considering the problem in this way the correspondence of distinguished geomorphological and geological units can be observed.

Within this frame, every and even the slightest exception from a common pattern of distinguished units is considered as an indicator.

The importance of indicators only by themselves is relative. However, clustered in one particular locality, they have already hit the target.

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