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Upper Permian Evaporites and Associated Rocks of Dalmatia and Borderline Area of Lika and Bosnia

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Key words: Dalmatia, Lika, Bosnia, evaporites, gypsum, anhydrite, clastics, carbonates, volcanites, palynomorphs, Upper Permian

In the region of Central and North Dalmatia, as well as in the southeastern Lika and western Bosnia, the evaporite complex composed mainly of gypsum and anhydrite and associated rocks: clastics, carbonate and somewhere volcanites have been investigated. The lithological and petrographical characteristics of these sediments, their interrelationships and relations with Mesozoic, Paleogene and Neogene strata have been shown. Also, the palynological analyses prove Upper Permian age of the evaporite complex for the first time. This conclusion has been supported with the geochemical and mineralogical data as well.

Ključne riječi: Dalmacija, Lika, Bosna, evaporiti, gips, anhidrit, klastiti, karbonati, vulkaniti, palinomorfa, gornji perm

U srednjoj i sjevernoj Dalmaciji, jugoistočnoj Lici i zapadnoj Bosni istraživan je evaporitni kompleks koji se sastoji od gipsa i anhidrita te pratećih stijena: klastita, karbonata i mjestimično vulkanita. Prikazane su litološke i petrografske karakteristike ovih naslaga, njihovi međusobni odnosi te odnosi s mezozojskim,u paleogenskim i neogenskim sedimentima. Palinološkim analizama prvi put je dokazana gornjopermska starost evaporitnog kompleksa što potvrđuju geokemijska i mineraloška istraživanja.

1. INTRODUCTION

In middle and northern Dalmatia, and in the bordeline area between Lika and Bosnia (Fig. 1) a detailed geological investigation of evaporites (gypsum and anhydrite) and associate deposits of Upper Permian was carried out. Also, numerous localities in SW Bosnia and, partly, Herzegovina have been surveyed (Fig.5). This investigation, in which numerous experts from various institutes took part, is shown in three annual reports and in a final study: "Geological investigations of the evaporites and associated deposits of Dalmatia, Lika and south-western Bosnia and Herzegovina" carried out by the Institute of Geology, Zagreb for the company "INA-Naftaplin - Research Survey", Zagreb.

The aim of these investigations was to determine the age of evaporites and associated deposits, their mutual superposition and tectonic relations, and to indicate the possible position of evaporites in the structural complex of the investigated part of the Dinarides with regard to the tectonic evolution. With these investigations petrographic, mineralogical and chemical characteristics of evaporites and associated Upper Permian rocks were determined, as well as the type of environment and conditions for their sedimentation . The solution of the above geological problems required a complex approach. For this purpose a geological map was produced, scale 1:25.000 surface approximately 500 km² (Fig. 1) an area with outcrops of the investigated Upper Permian sediments which encompassed the remaining deposits with which they are in contact. This geological map, of which two sections are shown here as an illustration of the determined geological relations (Fig. 2,3), was produced by K. SAKAČ, A. ŠUŠNJARA, A. GABRIĆ, V. PENCINGER and B. LUKŠIĆ. Numerous detailed geological columns of the clastic Upper Permian deposits were recorded during field investigations. Extensive sedimentological, petrographic, paleontologic and geoochemical investigations were carried out on a large number of collected selected samples. Aerial and satellite photographs were analysed, and with a representation of the already existing geophysical maps and seizmic profiles, a review was made of the possible position of evaporites in the whole structural-tectonic complex, during which a new classification of the faults and other tectonic elements of regional importance was made.

In this work only a part of the results of the above investigations is presented. They refer to the lithological and petrographic characteristics and to the age and mutual relations of evaporites and associated Upper Permian deposits. The results of the other investigations will be presented in separate works.

This work partly incorporates the results given in annual reports on microscopic investigations of the composition and structure of rocks carried out by B. ŠĆAVNIČAR, J. TIŠLJAR, Al. ŠIMUNIĆ and S. NOVOSEL-ŠKORIĆ, and also isotopic analyses of sulphur from evaporites by T. DOLANC and J. PEZDIĆ.

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Palynological examinations were carried out by B. JELEN.

2. REVIEW OF FORMER INVESTIGATIONS ON EVAPORITES IN THE MIDDLE PART OF THE DINARIDES

Numerous authors have studied the stratigraphic and tectonic position and general characteristic of evaporites and associated rocks in the middle part of the Dinarides. The differences in age which appear in these works occurred because of the lack of reliable paleontological documentation and the complex tectonics of an area with evaporites.

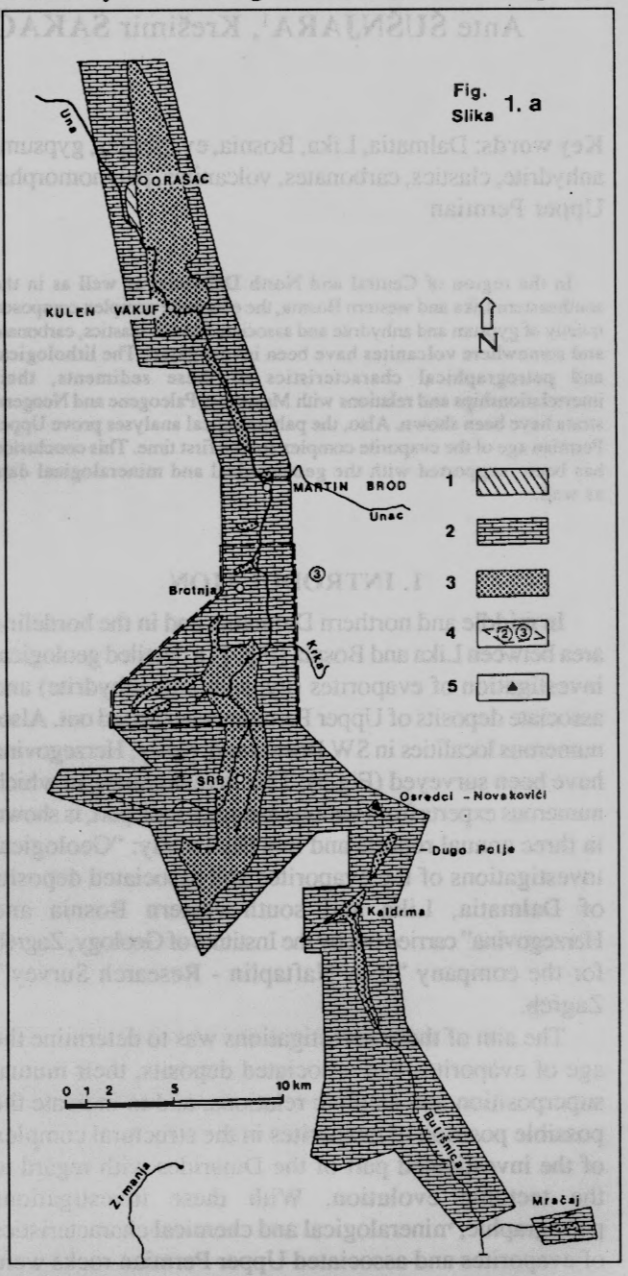
FOETERLE (1862), HAUER (1868) and MOJSISOVICS et al. (1880) were the first to present the data on evaporites in the above region.

They classify them, together with associated carbonate and clastic deposits, in the "Werfenian" deposits of the Lower Triassic. At that time such an opinion was also accepted by other authors, for example, STACHE (1889), KERNER (1901, 1916,1920), KOCH (1914 a, b), and SCHUBERT (1920). They showed distribution of gypsum in the interior of Dalmatia and Lika in more detail. Thus gypsum is classified as the Permian in age and associated clastics as Lower Triassic in age. At the same time FRANIĆ (1900), KIŠPATIĆ (1901) and ŠUKLJE (1914) described the significant occurrences of gypsum in the surroundings of Srb in Lika.

KATZER (1903,1921,1925) was the first one who described in more detail the gypsum beds in Bosnia and Herzegovina. He considered that they were Permian in age. PODUBSKY (1963,1976) analysed in more detail the beds of these evaporites. He believed that the evaporites were sedimented in the Permian in an epicontinental and not in a lagoonal environment, and that the sedimentation continued in the Lower Triassic with the deposition of carbonate rocks and clastics. Later ČIČIĆ (1987) proposed the Permian age of gypsum and anhydrite beds of Bosnia and Herzegovina, i.e. former Yugoslavia. This was in accordance with the data of several authors.

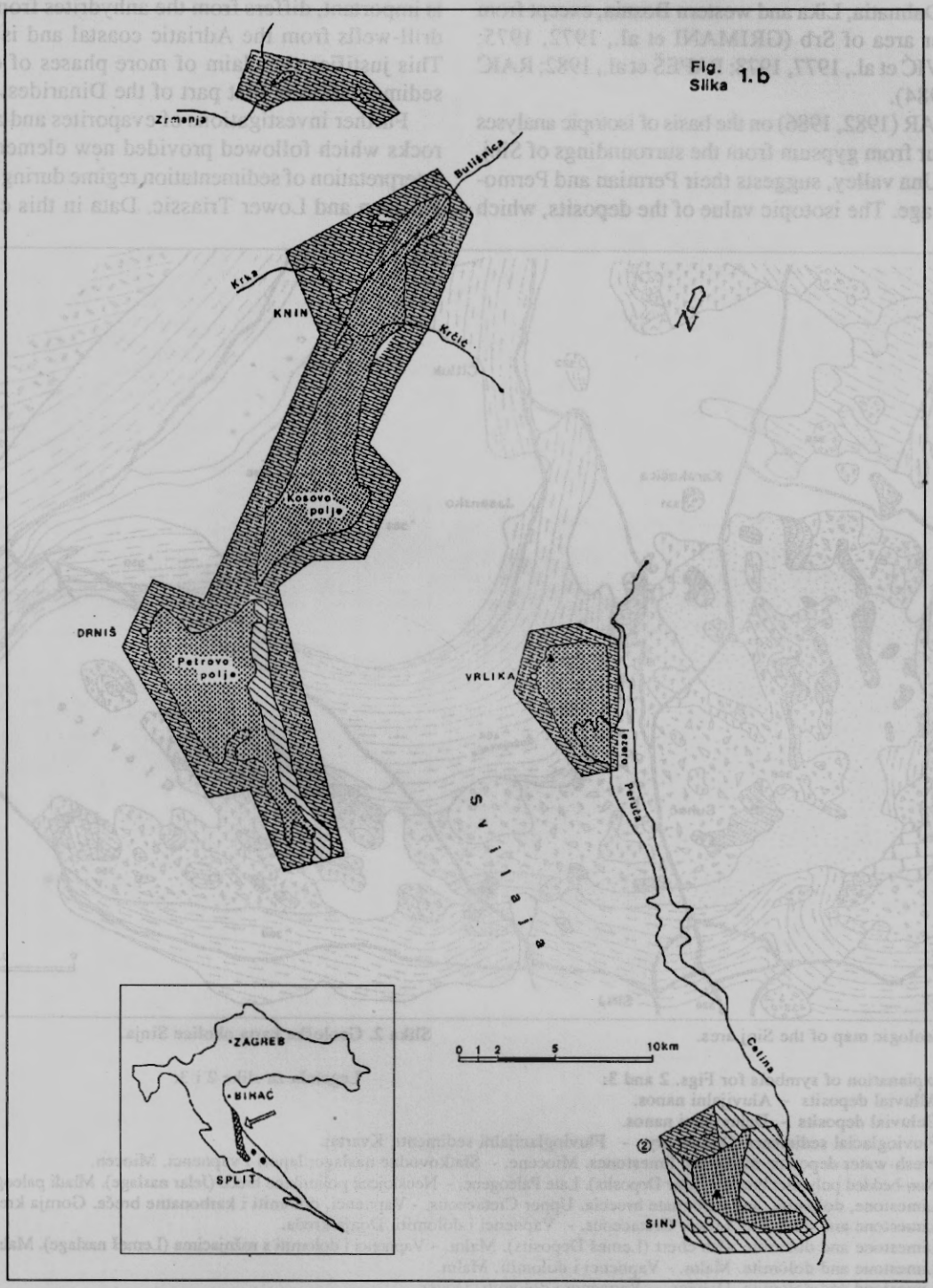
As the above investigations did not provide any direct evidence of the age of the evaporites, a dilemma appeared with regard to their stratigraphic position, when, while drilling in the Adriatic area, anhydrites were found within the Upper Triassic deposits (island of Krk), i.e. Jurassic and Cretaceous (Dugi otok, Olib, Brač, Montenegrian coastal region, which was reported by ČANOVIĆ (1969), BOŠKOV-ŠTAJNER (1971),KRANJEC (1979), ĐURASEK et al. (1981), BLAŠKOVIĆ (1983) and others. In an attempt to connect the stratigraphic position of evaporites from the Adriatic area with those in the interior of the middle part of the Dinarides ŠUŠNJAR et al.(1965), ŠUŠNJAR & BUKOVAC (1978, 1979) and ŠUŠNJAR (1981, 1983) presented a different interpretation of the paleogeographic relations in the Mesozoic with partial alternation of the stratigraphic sequence of individual deposits and their tectonic position along the Una valley and part of the middle Dalmatia. Thus, evaporites and associated clastic sediments of this area were classified in the Malm, others would correspond to the transition of the Malm into the Lower Cretaceous (Osredci at Srb), i.e. to the transition of the Lower into the Upper Cretaceous (Martin Brod in the Una valley).

However, investigations of the other authors supported earlier opinions on the Permian or Permian-Triassic age of evaporites. Consequently, IVANOVIĆ et al. (1971) in an analysis of lithological characteristics of evaporites



Figs. 1a and 1b. Areas of investigation.
Slike 1a i 1b. Područja istraživanja
Explanation of symbols:
Legenda:

1. - Neogene deposits - Neogenski sedimenti
2. - Mesozoic and Paleogene deposits - Mezozojske i paleogenske naslage
3. - Upper Permian deposits, partly covered with Quaternary formations - Gornjopermske naslage, djelomično pokrivene kvartarnim tvorevinama
4. - Situation of Figs. 2 and 3 - Položaj slike 2 i 3
5. - Pollen analysis sites - Nalazišta polena



and clastics in middle Dalmatia found that they belong to the interval of the Upper Permian - Lower Triassic. SAKAČ et al. (1970) found in the top part of clastics paleontological evidence of the Lower Triassic fossils. HERAK (1973, 1983) refused the above opinion on the mainly Malm age of evaporites in the cited area of Dalmatia and Lika and considered the possible conditions of their deposition in the lagoonal environment during the Upper Permian or Permo-Triassic, and emphasizes their importance in the tectonics, as they are situated mainly on the overthrust fronts in tectonic windows, etc. In the same way CHOROWICS (1975, 1977) interpreted the position of evaporites along the regional dislocation Karlovac-Knin. He found new important details, such as the overthrust of the Triassic deposits of Stražbenica, the tectonic window of Suvaja, and other complicated tectonic relations in a wide area at Srb. BAHUN (1985) classified evaporites in the same area in the Permo-Triassic, referring to the extensive Jelar deposits as an indicator of the complex tectonic movements in the Tertiary.

Opinion on the "Permo-Triassic" age of evaporites and associated carbonates and clastic rocks prevailed during the production of detailed geological maps in

parts of Dalmatia, Lika and western Bosnia, except from the wider area of Srb (GRIMANI et al., 1972, 1975; IVANOVIĆ et al., 1977, 1978; PAPEŠ et al., 1982; RAIĆ et al., 1984).

ŠIFTAR (1982, 1986) on the basis of isotopic analyses of sulphur from gypsum from the surroundings of Sinj, and the Una valley, suggests their Permian and Permo-Triassic age. The isotopic value of the deposits, which is important, differs from the anhydrites from the deep drill-wells from the Adriatic coastal and island area. This justifies the claim of more phases of evaporitic sedimentation in that part of the Dinarides.

Further investigations of evaporites and associated rocks which followed provided new elements for the interpretation of sedimentation regime during the Upper Permian and Lower Triassic. Data in this connection

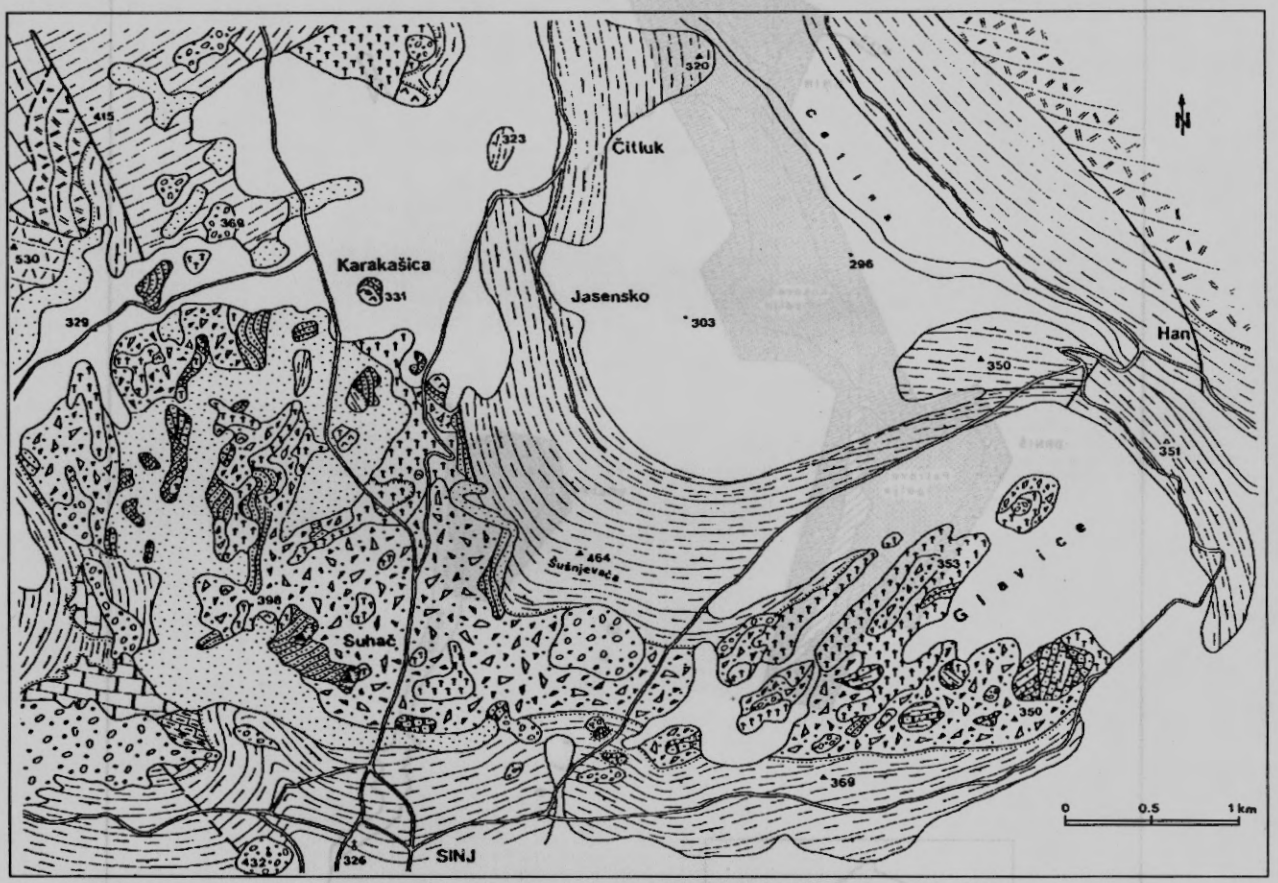


Fig. 2. Geologic map of the Sinj area.

Slika 2. Geološka karta okolice Sinja.

Explanation of symbols for Figs. 2 and 3: Legenda za slike 2 i 3:

1. - Alluvial deposits - Aluvijalni nanos.
2. - Deluvial deposits - Deluvijalni nanos.
3. - Fluvioglacial sediments. Quaternary. - Fluvioglacijalni sedimenti. Kvartar.
4. - Fresh-water deposits; marls and limestones. Miocene. - Slatkovodne naslage; lapori i vapnenci. Miocen.
5. - Non-bedded polymict breccia (Jelar Deposits). Late Paleogene. - Neuslojene polimiktne breče (Jelar naslage). Mlađi paleogen.
6. - Limestone, dolomite, and carbonate breccia. Upper Cretaceous. - Vapnenci, dolomiti i karbonatne breče. Gornja kreda.
7. - Limestone and dolomite. Lower Cretaceous. - Vapnenci i dolomiti. Donja kreda.
8. - Limestone and dolomite with chert (Lemeš Deposits). Malm. - Vapnenci i dolomiti s rožnjacima (Lemeš naslage). Malm.
9. - Limestone and dolomite. Malm. - Vapnenci i dolomiti. Malm.
10. - Limestone and dolomite. Dogger. - Vapnenci i dolomiti. Doger.
11. - Limestone and dolomite. Lias. - Vapnenci i dolomiti. Lijas.
12. - Limestone and dolomite with clastic intercalations. Ladinian. - Vapnenci i dolomiti s uloščima klastita. Ladinik.
13. - Limestone and dolomite with clastic intercalations. Anisian. - Vapnenci i dolomiti s uloščima klastita. Anizik.
14. - Carbonate deposits. Upper Scythian - Karbonatne naslage. Gornji skit.
15. - Clastic and carbonate sediments. Lower Scythian. - Klastični i karbonatni sedimenti. Donji skit.
16. - Porous carbonate breccia ("rauhwacke"). Permian, pre-Neogene, and Quaternary.
    - Šupljikave karbonatne breče ("rauhwacke"). Perm, predneogen i kvartar.
17. - Clastic deposits: pelite, siltite, and sandstone. Upper Permian. - Klastične naslage: peliti, siltiti i pješčenjaci. Gornji perm.
18. - Limestone and dolomite. Upper Permian. - Vapnenci i dolomiti. Gornji perm.
19. - Evaporites: gypsum and anhydrite. Upper Permian. - Evaporiti: gips i anhidrit. Gornji perm.
20. - Albitized basic igneous rocks. Upper Permian? - Albitizirani bazični eruptivi. Gornji perm?
21. - Dip-strike symbols. - Elementi nagiba sloja.
22. - Geologic boundary: 1 normal; 2 gradual transition; 3 transgressive.
    - Geološka granica:1 normalna, 2 postupni prijelaz, 3 transgresivna.

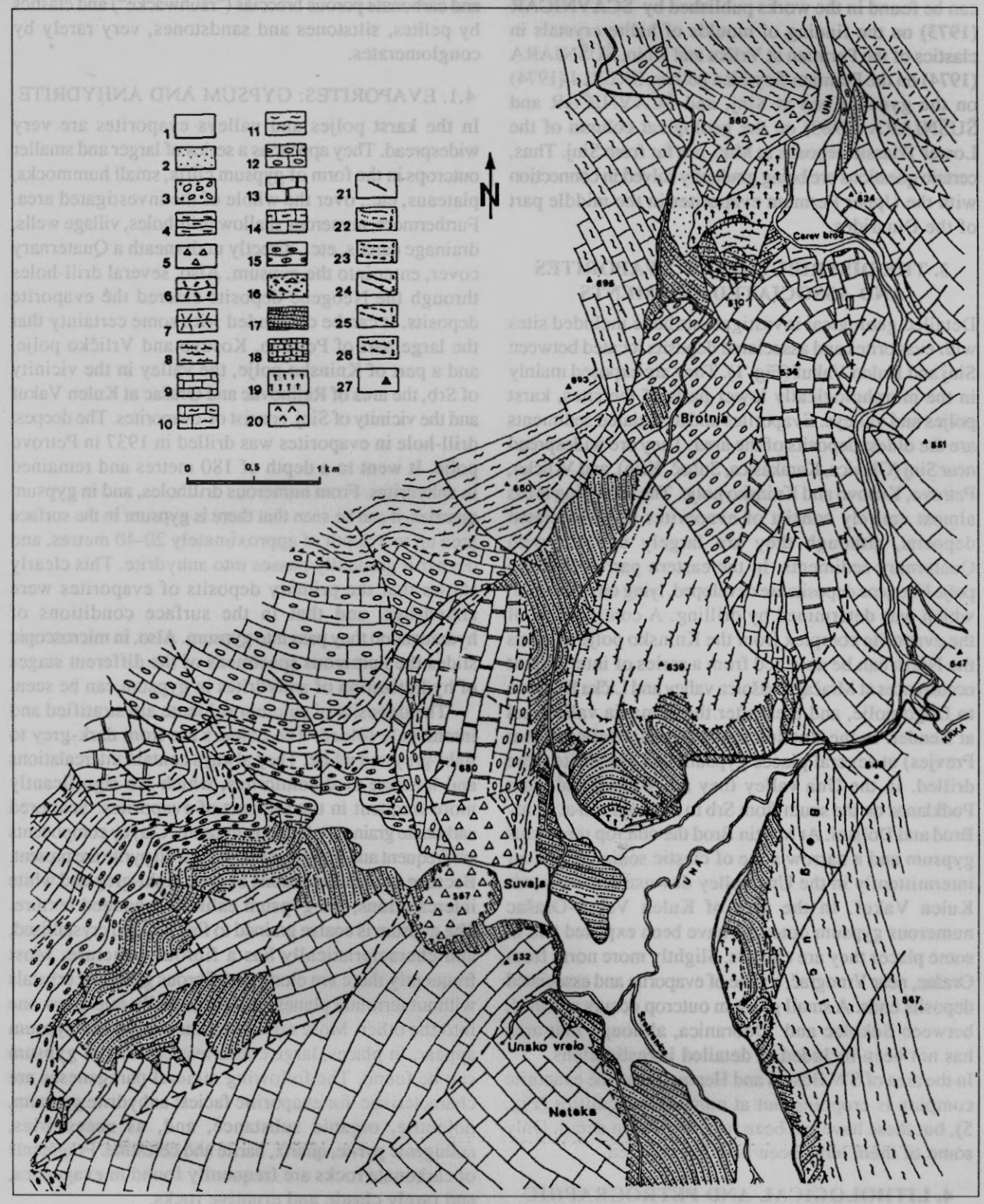


Fig. 3. Geologic map of the Una River spring area.

Slika 3. Geološka karta šireg područja oko vrela Une

23. - Geologic boundary, approximately located (1 normal, 2 gradual transition, 3 transgressive).
- Geološka granica aproksimativno locirana (1 normalna, 2 postupni prijelaz, 3 transgresivna).
24. - Faults (1 normal, 2 reverse). - Rasjedi (1 normalni, 2 reversni).
25. - Faults (1 normal, 2 reverse), approximately located or assumed - Rasjedi (1 normalni, 2 reversni) aproksimativno locirani ili pretpostavljeni).
26. - Overthrust contacts (1 established; 2 approximately located or assumed).
- Navlačni kontakti (1 utvrđeni, 2 aproksimativno locirani ili pretpostavljeni).
27. - Pollen analysis sites. - Nalazišta polena.

can be found in the works published by ŠĆAVNIČAR (1973) on the finding of moulds of halite crystals in clastics of the Permian at Vrlika and Knin, ŠUŠNJARA (1974) on the Permian-Scythian pelites, SKERLJ (1974) on the gypsum bed at Sinj, and ŠĆAVNIČAR and ŠUŠNJARA (1983) on the geological column of the Lower Triassic deposits at Muć, not far from Sinj. Thus, certain questions are being gradually solved in connection with the Upper Permian evaporites in the middle part of the Dinarides.

3. THE DISTRIBUTION OF EVAPORITES AND ASSOCIATED SEDIMENTS

Detailed geological investigations have included sites with evaporites and associated deposits located between Sinj and Kulen Vakuf (Fig. 1). They are exposed mainly in the morphologically lower parts of the sites, karst poljes and valleys. Evaporites and associated sediments are the oldest deposits of the area. They are widespread near Sinj (Glavica, Karakašica, Suhač, Krin), and Vrličko, Petrovo, Kosovo and Kninsko polje. The foregoing areas almost entirely consist of evaporites and associated deposits, although they are largely covered with Quaternary sediments. In the eastern part of Petrovo polje Neogene deposits are developed, lying on evaporites, which was determined by drilling. A continuation of the evaporite complex from the Kninsko polje towards the North can be detected from a series of intermittent occurrences at Mračaj Butišnica valley and Lička Kladrma to Dugo polje, and thereafter the Zrmanja valley and at Bender. In the Butišnica and Zrmanja valleys (near Prevjes) at several places gypsum and anhydrite were drilled. In the Una valley they are widespread from Podklanac on the south from Srb to Brotinja and at Carev Brod and Doljani. At Martin Brod the outcrop represents gypsum and a narrow zone of clastic sediments occur intermittently in the Una valley downstream towards Kulen Vakuf. In the area of Kulen Vakuf-Orašac numerous gypsum outcrops have been exposed and in some places they are clastics. Slightly more north from Orašac, near Vrnograč, a zone of evaporite and associated deposits ends. A small gypsum outcrop occurs at Bihać, between Sokolac and Dobranica, although that area has not been included in detailed investigations.
In the area of SW Bosnia and Herzegovina, the evaporite complex is cropping out at numerous localities (Fig. 5), but these have not been investigated in detail. Only some of them have been briefly surveyed.

4. LITHOLOGICAL AND PETROGRAPHIC CHARACTERISTICS OF EVAPORITES AND ASSOCIATED DEPOSITS OF THE UPPER PERMIAN PERIOD

The Upper Permian contains evaporites, clastics and carbonate sediments, to which numerous smaller occurrences of eruptive rocks are connected. The evaporites are represented as gypsum and anhydrites. Carbonates are represented by dolomites, limestones and carbonate porous breccias ("rauhwacke") and clastics by pelites, siltstones and sandstones, very rarely by conglomerates.

4.1. EVAPORITES: GYPSUM AND ANHYDRITE

In the karst poljes and valleys evaporites are very widespread. They appear as a series of larger and smaller outcrops in the form of gypsum cliffs, small hummocks, plateaus, etc., over the whole of the investigated area. Furthermore, numerous shallow drill-holes, village wells, drainage canals, etc., directly underneath a Quaternary cover, enter into the gypsum. Also, several drill-holes through the Neogene deposits entered the evaporite deposits. It can be concluded with some certainty that the large part of Petrovo, Kosovo and Vrličko polje, and a part of Kninsko polje, the valley in the vicinity of Srb, the area of Rajinovac and Orašac at Kulen Vakuf and the vicinity of Sinj, consist of evaporites. The deepest drill-hole in evaporites was drilled in 1937 in Petrovo polje. It went to a depth of 180 metres and remained in anhydrites. From numerous drillholes, and in gypsum quarries, it can be seen that there is gypsum in the surface area up to a depth of approximately 20-40 metres, and deeper it gradually passes into anhydrite. This clearly shows that the primary deposits of evaporites were anhydrites, and that in the surface conditions of hydratization they pass into gypsum. Also, in microscopic slides the numerous specimens of the different stages of hydratization of anhydrites in gypsum can be seen.

The deposits of calcium sulphate are stratified and intensively folded. The colours are from dark-grey to light-grey and white. They always contain intercalations and laminae of dolomicrites, which are significantly more frequent in the top part of evaporites. Scattered carbonate grains are found in gypsum. Clayey components are frequent and organic substances with pyrite are present. Because of the alternations of grey, light-grey and white intercalations, the gypsum exhibits a banded texture. The gypsum is coarse grained to fine grained crystallised, and characteristically has a fibrous structure. Most frequently there are elongated fibrous grains or crystals without terminal planes, which mutually intergrow one into the other. More rarely regular crystals of gypsum appear. In places, large colourless crystals of gypsum can be found. The following mineral parageneses are characteristic for evaporitic facies: anhydrite,gypsum, dolomite, organic substance, and, as accessories, authigenic pyrite, quartz, barite and celestine. Fragments of carbonate rocks are frequently found in evaporites, and rarely clastic and eruptive rocks.

4.2. LIMESTONES AND DOLOMITES

The largest occurrence of limestones and dolomites can be found in Glavica, not far from Sinj. Small occurrences are found in other areas around Sinj, Vrlika and in Petrovo polje. They are mainly associated with porous breccias.

Dolomites alternate with evaporites or they are found

as intercalations in limestones.Their colour is ash-grey to black. They belong to early diagenetic criptocrystalline dolomites (dolomicrytes). They always contain organic substance, and fine crystals of authigenic quartz can be observed.

Limestones are also characteristized by good stratification, and in places by lamination. Their colour is grey, dark-grey and black from an admixture of bituminous substances. They are often crosscutted with white calcitic veins. In the area of Labrović (near Sinj) and Umljanović (near Drniš), beautiful fluorite crystals are located in limestones in white calcitic veins. BARIĆ (1969) linked the genesis of fluorite from the Sinj region with eruptive rocks. The structure of the limestone is microcrystaline. They are rarely affected by dolomitization. In places they contain authigenic quartz with well developed idiomorphic crystals and clear terminal surfaces. Poorly preserved fragments of thin mollusk shells can be seen in limestones.

4.3. POROUS CARBONATE BRECCIAS

Carbonate porous breccias, in older literature known by the name "Rauhwacke", are connected with the evaporitic complex of deposits. In the investigated area they are abundant. They are most numerous in Kosovo polje and at Sinj. They are of a small thickness, although in places this thickness is maybe over 30 meters. They are always non-stratified. In places they occur as greater or smaller weakly connected blocks, while in other places they are connected in a very firm rock. In places they appear like dross. The colours are most often brownish or dark-grey. They are characterised by numerous small holes up to 2 cm which are often level surfaces or a system of unevenly formed small channels. In the fine grained calcareous matrix, often spongy to honey-combed pattern (tufa-like) calcareous and dolomitic fragments are found of sometimes unclear forms. In places dolomitization of irregular forms in the cement and fragments can be seen, which increases the breccial appearance of the rock. Breccias are partially silicified. Fragments of rocks in the breccias are most frequently angular, and rarely sub-rounded, and usually unsorted. Fragments and blocks of rock in the breccias usually originate from the Permian limestones and dolomites. Possibly, a part of the fragments originates from the base of the Lower Triassic deposits which can be found in Podkonje and on Milića glavica. Fragments of the Permian clastics have been determined, as well as few fragments of igneous rocks and gypsum. On the breccias one can find rare fragments of the Upper Mesozoic and Paleogene rocks, most often Cretaceous limestones which are not a primary content of these deposits. Fragments of younger rocks are deposited in breccias entirely by fissures or during the sedimentation of breccias.

4.4. CLASTIC DEPOSITS: PELITES, SILTSTONES AND SANDSTONES

A large and entire zone of exposed clastics is located in the eastern part of the Kosovo polje, Vrličko polje at Garjak, in Petrovo polje and in Suhač at Sinj, at Srb and on Čulumak in Rajinovci, and numerous smaller occurrences over the whole of the investigated area. Clastic deposits are usually well stratified; the only slightly poorer stratification can be seen in pelites at Garjak. They are very folded and the microfolding is especially marked, which is to be expected because of the type of the deposits and very significant tectonic events in this area and the influence of diapirism.

Clastics are represented by pelites, siltstones and sandstones, and very rarely conglomerates. In the series of clastic deposits pelitic sediments are dominant. Sandstones are more frequent in Kosovo polje and at Srb than in other areas. Clastics are calcareous in some places. The colours are red and grey to grey-greenish, and in places, such as in Suhač (a new cut) at Sinj and Ćulumak near Kulen Vakuf, they are dark-grey to black. In the whole area they are dominantly red and frequently there are alternations of red and grey. The analyses show that red and grey clastics have an almost identical mineral composition. The differences that can be seen in the colours are probably the result of conditions of sedimentation, and the different oxidational state of the iron in the minerals which are in red varieties of haematite and goethite, and in grey, pyrite. By special analyses of microelements it was also determined that in the red varieties there is an excess of manganese and in the green varieties, chromium. It would lead to the conclusion that the red clastics are deposited in an oxic environment, and the grey and dark-grey in a more reductive environment with the presence of an organic substance.

Pelites, besides the basic component clay minerals: illite, montmorillonites, kaolinites and hydromuscovites, usually contain calcite, chlorite, muscovite, feldspar and fine grains of quartz also. In pelites, fine lamellar cleavage and parallel stratification, because of planar arrangement of the lamellar minerals, are marked. They often belong to carbonate shales.

In siltstones, and particularly sandstones, a content of clayey component decreases, and the participation of silto-psamitic terrigenous detritus increases: quartz, feldspar, muscovite, chlorite and particles of rocks (microquartzite, quartzose schists, etc.). Sandstones have a high content of quartz which usually exceeds 75% of the total detritus present. A dominant type of cement is chemogenic quartzose cement, while the matrix of detrital origin is rarely found. Sandstones are rarely represented by types of grauwacke (quartzose, feldspathic and micaceous). Often, they are subarkoses (quartzose and micaceous), and quartzarenite and quartzlithoarenite. These types of sandstones indicate a connection with the highest levels of the Gröden facies from other areas of the western Dinarides. The composition and characteristics of the heavy minerals point to this connection even more, and the following minerals have been determined: pyrite, goethite, haematite, zircon, tourmaline, rutile and apatite (IVANOVIĆ et al., 1971).

In clastic rocks authigenic carbonate minerals are

often present in variable amounts (mainly calcite, sporadically dolomite). Calcite is fine grained and most frequently evenly scattered in the primary matrix.

A small amount of quartzose conglomerates was found in Kosovo polje at Milić glavica and in Orašac at Kulen Vakuf.

This connection between the described clastic rocks and the evaporitic facies was also indicated by the moulds of halite crystals which were found in these deposits at several places in Sinjsko, Vrličko and Kosovo polje, as well as in the Una valley (ŠĆAVNIČAR, 1973).

4.5. ALBITIZED BASIC ERUPTIVES

Although the small outcrops are the most frequent in the investigated area, numerous occurrences of eruptive rock surfaces have been discovered from several tens to several hundreds of square meters. Some of these occurrences were not registered earlier. As previously mentioned they are connected exclusively to the Upper Permian evaporitic complex of deposits.

Igneous rocks in this area were first mentioned by FORTIS (1774) and thereafter by HACQUET (1785), HAUER (1867), KIŠPATIĆ (1892), KERNER (1916) and other authors. BARIĆ (1957 and 1969) described in detail igneous rocks from the surroundings of Sinj, Vrlika, Petrovo polje and Knin, stating that they were albitized diabases.

Several samples of igneous rocks from the area of Sinj and Vrlika, which were investigated within the framework of this theme, are of the same composition and structure. They are hypabyssal coarse-grained rocks, belonging to altered albitized diabases. Effusive eruptive rocks from the area of the Una valley have not been precisely determined because of weathering, but they probably belong to the same type of igneous rocks which we find within the evaporitic complex of Dalmatia.

5. GEOLOGICAL RELATIONS OF EVAPORITES AND ASSOCIATED DEPOSITS

The described Permain deposits, although represented by different lithological members, make up a unique entity which is mainly structurally and tectonically separate from the Mesozoic and Paleogene deposits, while Neogene sediments lie on them with a prominent angular and erosional discordance. However, primary contacts are mainly deranged by faults and particularly by diapiric movements of evaporitic complex of deposits. It is difficult to determine in the field where primary contacts are preserved and where they are deranged by diapirism.

There are probably Promina deposits in places that transgressively overlie the Upper Permian deposits. This is demonstrated by the similarity of the ground morphology with extension of the border between the Promina sediments and Upper Permian deposits in the area of Badanj, Umljanović and Markovac, and particularly the composition of basal Promina conglomerates east of the Krasići hamlet at Drniš (SAKAČ, 1970). At this locality numerous pebbles of Upper Permian sandstone can be seen in the composition of the Promina conglomerate, apart from other conglomerates. Of course, these contacts today are deranged by faults or diapiric movements.

The superpositional sequence and relation of the lithological members is not everywhere completely clear. Field observation of the geological relations is particularly hindered by a large Quaternary cover. However, in the area of middle Dalmatia and in the borderline area of Lika and Bosnia, it can be clearly seen that evaporites are the oldest, and that clastics and carbonate sediments lie on them. Clastics lie directly on evaporites, which was discovered in numerous exposed profiles (Veliki and Mali Kukor, Suhač, Ćulumak and elsewhere in Kosovo polje) and confirmed by drilling. Moreover, in the area of Kosovo polje, west of the Mirkovići hamlet (Fig. 4) and Petrovo polje on Kadina Glavica, and particularly at the first locality, multiple alternations of pelites and gypsum are clearly visible in thickness of several metres. However, deeper within the evaporites, intercalations of clastics have not been found anywhere. This indicates that clastics are in a normal sequence on evaporites, and rarely are found in the final phase of sedimentation of evaporites and sinsedimentary. The relation of carbonate facies - dolomites and limestones is similar, while the problem of carbonate porous breccias is particularly more complex. In the area of Sinj near the houses of Labrović and Dolić on outcrop in the top part of the gypsum deposits intercalations of gypsum with ash-grey dolomites are in alternation. Here it is quite clear that we are dealing with sinsedimentional alternations of evaporites and dolomites. This is followed, in not quite clear relations, by a thick formation of dark-grey and black stratified limestones and dolomites with intercalations of breccias. Intercalations of sinsedimentational dolomite in gypsum were determined in the drill-holes at Stipanovića Greben, as well as in the vicinity of Sinj, Mali Kukor at Kosovo polje, and some other places.However, in numerous open quarries and drill-holes it has been determined that significant occurrences of carbonate are not found in evaporites, except in the top parts of an evaporitic sequence where they appear as intercalations and thinner layers. Laminae, and more rarely thin layers, are present everywhere in evaporites. Thus, evaporites are covered by tens of meters thick clastic, and considerably more rarely, carbonate deposits.

Therefore it follows that carbonate and clastic deposits lie directly on evaporites, and it can be concluded that carbonates and clastics were sedimented at the same time but in different conditions. The clastics themselves are frequently calcareous and in places contain intercalations of limestones (Suhač, Vrlika, etc.).

Unfortunately, in the field, there was no evidence of direct contacts of carbonate deposits and clastics where their mutual relations could be studied in more detail. Only in the area of Vrlika, outcrops of black, laminary micritic limestones are observed within the clastic rocks.

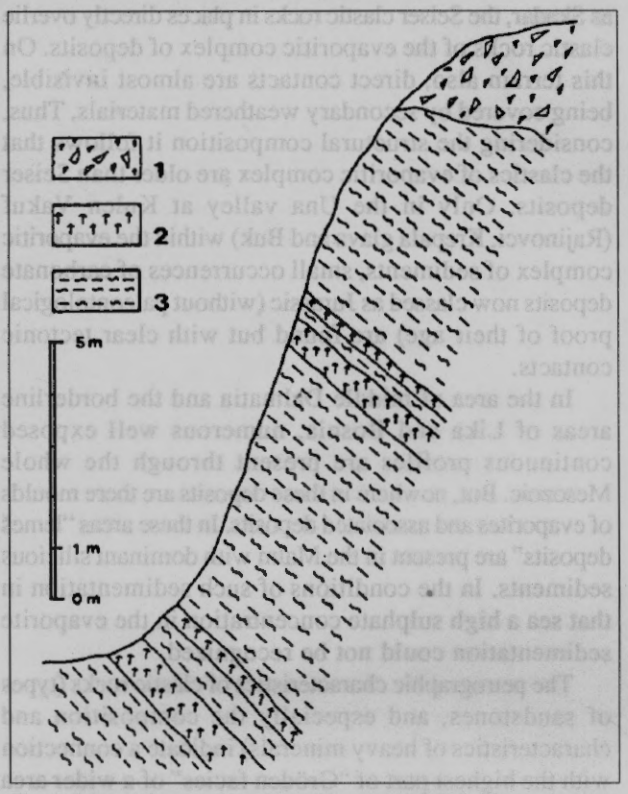


Fig. 4. Schematic representation of the gypsum-shale alternation near the Mirković village in Kosovo Polje.
Slika 4. Skica izmjene gipsa i šejla kod zaseoka Mirković u Kosovu polju.
Explanation of symbols:
Legenda:
1. - Porous carbonate breccia - Šupljikave karbonatne breče
2. - Gypsum - Gips
3. - Shale - Šejl

However, direct contacts are covered which means that their mutual relations are not clear, even in this locality, although the general impression is that limestones lie underneath the clastics.

Grey to dark-grey porous carbonate breccias, in literature known as "rauhwacke" are represented in the carbonate facies. They are always conected to areas with evaporites. They are often directly on gypsum. In places they are connected to the Upper Permian dolomites and limestones, which can be seen in the area of Umljanović and in the Vrba valley where two smaller hills are built from porous carbonate breccias. It can be seen that after exploatation of the surface portions for the needs of the construction industry, these breccias, towards the deeper parts, gradually pass into stratified, tectonic-broken dark--grey limestones. Apart from larger or smaller disjected blocks porous breccias can often be found on the gypsum.

In the area of Kosovo and Petrovo polje, and Sinj considerable masses of carbonate porous breccias exist. Their relation with other lithological members of the evaporitic complex is not entirely clear, although much attention has been given to this problem. Namely, direct contacts with other lithological members are regularly covered by Quaternary sediments. At a number of places on Kosovo polje large masses of carbonate breccias can be found, and in the immediate vicinity also thick deposits of clastic rocks.

IVANOVIĆ et al. (1971) state that the porous carbonate breccias near Orlić (Kosovo polje) are located between red clastics and Lower Triassic deposits, and conclude that they most probably belong to the Upper Permian - Lower Triassic transition, and "they could be coastal material formed in the Upper Permian along the borderline of emergent surfaces and the evaporitic basin, in a zone of alternative flooding and drainage". However, with a detailed examination of Milića Glavica near Orlić, where the Lower Triassic deposits lie directly on the Upper Permian, we did not discover any occurrences of porous breccias, but well stratified limestones and dolomites, lying in unclear relations on the Permian sandstones, while the clastics of the Lower Triassic lie over them. In the area of Veliki Kukor, Kulen Vakuf, and some other localities, porous breccias lie over the clastics, but as bigger or smaller, mostly disconnected blocks and fragments in clayey material, which indicates their secondary position, i.e. resedimentation in the Quaternary.

At Kosovo polje, in places at the foothills built of breccias, primary outcrops of Upper Permian clastic rocks are found, which indicate the possibility that these breccias at least lie partly on clastic rocks. However, their relation may be the outcome of tectonic events and erosional processes.

At Petrovo polje near St. Petka's church, Neogene deposits lie on the blocks of dark-grey porous breccias, with the Upper Permian clastics lying underneath breccias. In the Vrba valley and at several localities in Petrovo polje on the black porous breccias, lie loose or poorly cemented blocks and detritus of Cretaceous limestones (rarely dolomites), and Promina deposits (limestones and conglomerates). On the western side of Kadina Glavica, near Meštrović's mausoleum, Neogene sediments are found on such deposits. In the investigated area the base of the evaporite deposits had not been yet discovered and therefore the thickness of these beds remains unknown.

Igneous rocks, mostly albitised and sericitised diabases, exist in many places within the evaporitic complex of deposits in the entire investigated area. They are always small bodies, often morphologically prominent and of a conical shape. Eruptive rocks are mainly connected to clastics and evaporites. Unfortunately, direct contacts are regularly non-exposed.

6. AGE OF EVAPORITES AND ASSOCIATED ROCKS

A lot has been written on the age of evaporites and associated rocks. As these deposits are mainly devoid of fossils and are found in complicated structural-tectonic relations, conclusion on the age most frequently was brought on the basis of structural complex and direct contact with geological formations (the age of which had already been proved), and lithological similarity with known deposits. This can explain a variety of opinions about the age of these deposits.

This investigation focused particular attention on the solution of the question of the age of evaporites and associated deposits in the area of middle Dalmatia and borderline areas of Lika and Bosnia. Besides observations in the field, paleontological, geochemical and petrological methods were applied. The results obtained are in agreement and all indicate the Upper Permian age.

The geological framework of the evaporitic complex of deposits is made up of various members of Mesozoic and Cenozoic, but contacts are always of a fault-type and are of no great significance for the determination of the age of evaporites. In some rare cases, however, primary relations with the Lower Triassic deposits are preserved, which is very significant. At Patiera glavica at Petrovo polje KERNER (1901) mentions findings of the Lower Triassic deposits with fossils *Anodontophora fassaensis* WISSMANN, *Pseudomonotis* cf. *austriae* BITTNER, *Claraia clarai* EMMERICH and other forms. These Lower Triassic deposits are located within the complex of evaporites and associated deposits, and undoubtedly overlie them, although mutual relation is not visible, being covered by alluvial deposits. Similar relations exist at several localities in Kosovo polje. At Milića glavica Lower Triassic deposits directly overlie clastic rocks from the evaporitic complex of deposits. At Patiera glavica, as well as at Milića glavica, besides the Lower Triassic clastics, grey, stratified, late diagenetic dolomites and recrystallised limestones are found. Similar carbonate deposits are located in the village of Potkonje in the vicinity of the houses Požar between the Seiser deposits and evaporites, and also in a base of Lower Triassic at Muć.

IVANOVIĆ et al. (1971) state that at Ćulum, close to the village of Orlić, there is a location of Seiser micaceous sandstones with steinkerns and moulds of Pseudomonotis which directly overlie the clastics from the evaporitic complex of deposits. Also, at Kosovo polje, near the houses of Čenići and Žmiko, SAKAČ et al. (1970) determined a micro-fossil association belonging to the Lower Triassic, located in clastic deposits within the evaporitic complex. The significance of the mentioned localities is that the Lower Triassic deposits lie directly on clastics of an evaporitic complex, which surround them from all sides. This, also, indicates the Upper Permian age of evaporites and associated layers. In the western marginal area of Kosovo polje at the Konj and Potkonj localities Lower Triassic deposits are present, probably directly overlying the evaporitic complex of deposits, though direct contacts are not visible - covered by Quaternary deposits. Nowhere else in the whole area of middle Dalmatia were Mesozoic and Paleogene deposits discovered within the evaporitic complex. They form a tectonic framework in the marginal area of evaporites and associated deposits and have no great significance for the age of the evaporitic complex of deposits.

In Lika in the area of Gornja Suvaja, on the stretch from the hamlet of Jovanović through Đukić and as far as Skadar, the Seiser clastic rocks in places directly overlie clastic rocks of the evaporitic complex of deposits. On this terrain also, direct contacts are almost invisible, being covered by secondary weathered materials. Thus, considering the structural composition it follows that the clastics of evaporitic complex are older than Seiser deposits. Only in the Una valley at Kulen Vakuf (Rajinovci, Krepala glava and Buk) within the evaporitic complex of sediments, small occurrences of carbonate deposits now classed as Jurassic (without paleontological proof of their age) are found but with clear tectonic contacts.

In the area of middle Dalmatia and the borderline areas of Lika and Bosnia, numerous well exposed continuous profiles are present through the whole Mesozoic. But, nowhere in these deposits are there moulds of evaporites and associated deposits. In these areas "lemeš deposits" are present in the Malm with dominant silicious sediments. In the conditions of such sedimentation in that sea a high sulphate concentration in the evaporite sedimentation could not be recognized.

The petrographic characteristics of clastic rocks (types of sandstones, and especially the composition and characteristics of heavy minerals) indicate a connection with the highest part of "Gröden facies" of a wider area in the Dinarides (IVANOVIĆ et al., 1971). Also, on the basis of the petrographic characteristics of heavy minerals in the Vrličko polje occurrences ofs clastics of transitional type with the Upper Permian and Lower Triassic mixed characteristics were found.

Isotopic analyses of sulphur in the samples of gypsum and anhydrite from the outcrops and quarries from Dalmatia, Lika and the border area of western Bosnia have standardized values which vary from 9.07 to 13.66 with a mean value of 11.12. ŠIFTAR (1986) reported almost identical results of isotopic analyses of evaporites from the Una valley and middle Dalmatia. Mean isotopic value from 17 analyses is 10.7. According to ŠIFTAR (1986), DOLENC and PEZDIČ (quotations from the study report) it can be concluded on the basis of the isotopic composition that the evaporite deposits from the forementioned areas are of Upper Permian age.

Numerous remains of fossil plants have been found in the clastics but unfortunately they have not yet been determined. Rare and poorly preserved remains of macro-fossils found in the clastic and carbonate rocks have also not been determined. A few samples of limestone were analysed for conodonts, but no positive results were obtained. However, in the primary clastics (greenish-grey and dark-grey pelites) directly overlying gypsum at Suhač near Sinj a very rich palynological material was found.

The association of *Corisaccites alutas*, *Potonieisporites sp.*, *Lueckisporites virkkiae*, *Klausipollenites schaubergeri*, *Jugasporites delasaucei*, *Lunatisporites* sp. div., *Nuskoisporites dulhuntyi*, *Perisaccus granulatus*, *Gardenasporites heisseli*, *Gigantosporites aletoides*, *Strotersporites* sp., according to BRUGMAN (1983), determines the lower part of the

Upper Permian (in the tripartite division of the Permian). In the sample from the locality near Vrlika palynomorphs are badly preserved. The forms determined as cf. *Lueckisporites* and cf. *Gigantosporites* indicate the Upper Permian.

A sample of gypsum from Veliki Kukor (Kosovo polje) contained very rare pieces of undefinable dissacate pollen. Palynological analyses were carried out on samples of clastics from the area in the Una valley. A sample from the Ćulumak locality near Kulen Vakuf contains very rare dissacate coniferous pollen which, due to its poor condition, could not be determined. From the locality Osredci-Novakovići in the wider area of Srb the following forms were determined from samples of siltose pelites: *Lueckisporites virkkiae* Norm Aa, *Lueckisporites virkkiae* Norm Ab (dominant), *Lueckisporites virkkiae* Norm Ac, *Klausipollenites schaubergeri*, *Jugasporites delasaucei*, *Lunatisporites* sp. div., *Nuskoisporites dulhuntyi*, *Stroterspores* sp., which stratigraphically define the Upper Permian.

According to BRUGMAN (1983), the dominance of the Ab Norm within the Lueckisporites virkkiae phase characterizes the subphase 4. According to the same author the subphase 4 probably corresponds to the lower part of the Dzulfian stage.

These palynological determinations are generally the first paleontological evidence of the Upper Permian in evaporites and associated deposits at the investigated area, and undoubtedly reference can be made to the Upper Permian age of the clastics directly overlying the evaporites. The same stratigraphical position is present for limestones and dolomites. Evaporites, gypsum and anhydrite also belong to the Upper Permian with the possibility that the beginning of the evaporitic cycle might have belonged to the Middle Permian.

Taking into consideration all the above facts, as well as the genesis of evaporites and associated deposits, it can generally be said for the investigated areas that the beginning of evaporite sedimentation is definitely connected with the Upper Permian, and possibly the top part of the Middle Permian. The associated carbonate and clastic deposits belong to the Upper Permian, and that they at least in a part of the terrain probably continually spread into the Lower Triassic.

Dark-grey and grey carbonate porous breccias ("rauhwacke") are set aside without indication of age. With regard to the possible genesis of these breccias, where their origin is connected with the land conditions of weathering in tectonised evaporitic-carbonate sediments of the Upper Permian, the existence of several generations of these breccias can be presumed.

They could have been formed in the emersion of the Upper Permian following the sedimentation of the evaporites. It is possible that the majority of breccias were formed later in the process of tecto-genesis when evaporitic deposits broke out on to the surface. The possibility of the resedimentation of breccias, especially in the Quaternary, should be taken into consideration. With the in-the-field examinations the breccias of the Upper Permian, Pre-Neogene and Quaternary age were defined with cortairty, while all others remain in the field of assumption.

The age of the igneous rocks presents a special problem. KERNER (1916) states that the diabases occur in the form of veins which partly penetrate the "rauhwacke", lying in the bed of the Triassic, and partly even the Lower Verfenian schists. One vein of the diabase porphyry also penetrates the Upper Verfenian layers. On the basis of these data the eruptives can be ascribed to the Middle Triassic. This opinion on the Middle Triassic age of the igneous rocks from the surroundings of Sinj, was later accepted by all explorers for all occurrences of eruptives in the area of middle Dalmatia. IVANOVIĆ et al. for the first time (1978) when referring to the igneous rocks from Kosovo polje, Petrovo polje and near Vrlika, state that the Permo-Triassic clastics, occurring with volcanites, contain volcanic rock fragments and identical heavy minerals, which means that diabases had existed before the clastics were formed. Furthermore, widespread occurrences of the secondary growth of quartz in clastics, together with authigenic quartz crystals and authigenic tourmaline, point to the active effect of volcanism. Accordingly, it can be assumed that volcanites are of the same age or somewhat older than the Permo-Triassic clastics.

PAMIĆ (1982) explains albitised diabases from the area of middle Dalmatia, including a wider area of Outher Dinarides (Vanjski Dinaridi), by Triassic volcanism. RAIĆ et al. (1984) in an explanation for the Sinj newspaper allows the possibility that the spilitised diabases from the Sinj area may even be of Neogene age.

These investigations determined that the albitised diabases are connected with the Upper Permian complex of sediments. Fragments and pebbles of albitised diabases are found in evaporites, clastics and porous breccias. In the surroundings, and even in wider areas, within the Lower Triassic deposits of wide distribution, no occurrences of igneous rocks have been discovered. In the middle Dalmatia and in the borderline area of Bosnia (on the southern slopes of Svilaja, north of Knin, near Bosansko Grahovo, and others) the occurrences of igneous rocks connected to the Middle Triassic volcanism, are present. However, these are effusive rocks, basalts, associated with tuffs, connected with submarine effusions (ŠĆAVNIČAR et al., 1984), while hypabyssal rocks are present in the Permian deposits. As we are dealing with the veinal rocks, without detailed research, it is not recommended that conclusions are made on their age. Quite rare findings of fragments, and even pebbles, of these eruptives in evaporites and clastics, as well as a lack of igneous rocks in the Lower Triassic deposits, suggest the Upper Permian age.

7. A REVIEW OF THE EVAPORITES OF WESTERN AND SOUTHWESTERN BOSNIA AND HERZEGOVINA

An examination of the occurrence of evaporites and associated deposits in the area of western and south-

western Bosnia and Herzegovina (Fig. 5) revealed significant factors which indicate their stratigraphic and tectonic position and also the similarity in development and occurrence with the evaporitic complex of deposits in the investigated areas of Dalmatia and the Una valley. The evaporites occur along significant tectonic dislocations. The majority of sites are linked with Permian or Lower Triassic deposits.

On several localities in the immediate roof pendant of evaporites there are pelitic-carbonate deposits in which fossil remains were not found, and thus on the basis of the superposition in the sheets of the Basic Geological Maps, Scale 1:100 000 were classified in the Permo-Triassic. These sediments normally pass into deposits in which the Lower Triassic age was established, so they could belong to the Upper Permian. On some locatilities evaporites were linked with the red, typically Upper Permian clastics. But, it was not entirely clear whether these clastics were underlying evaporites or whether the evaporites were intercalated in the clastics. In this area, as in the investigated areas in Dalmatia and in the border areas of Lika and Bosnia, porous carbonate rocks, the so-called "rauhwacke" are frequently found on the evaporites, and are often broken into larger or smaller blocks. Interestingly enough, on the sites around the Ljubinačka river, the "rauhwackes" are found as "lens-like" bodies concordantly intercalated in the Upper-Permian red clastics, and are not in direct contact with evaporites.

It can be concluded that evaporites in the area of western and south-western Bosnia and Herzegovina are also of the Upper Permian age. This was proved by the results of the isotopic analyses of sulphur from gypsum and anhydrite performed by J. PEZDIČ, and the petrographic analyses of J. TIŠLJAR and AL. ŠIMUNIĆ. The petrological characteristics of evaporites are very similar to or identical with the evaporites from the area of Dalmatia and the Una valley. Gypsum is present on the surface, and anhydrite in deeper parts of the terrain. Intercalations and laminae of dolomicrytes are present

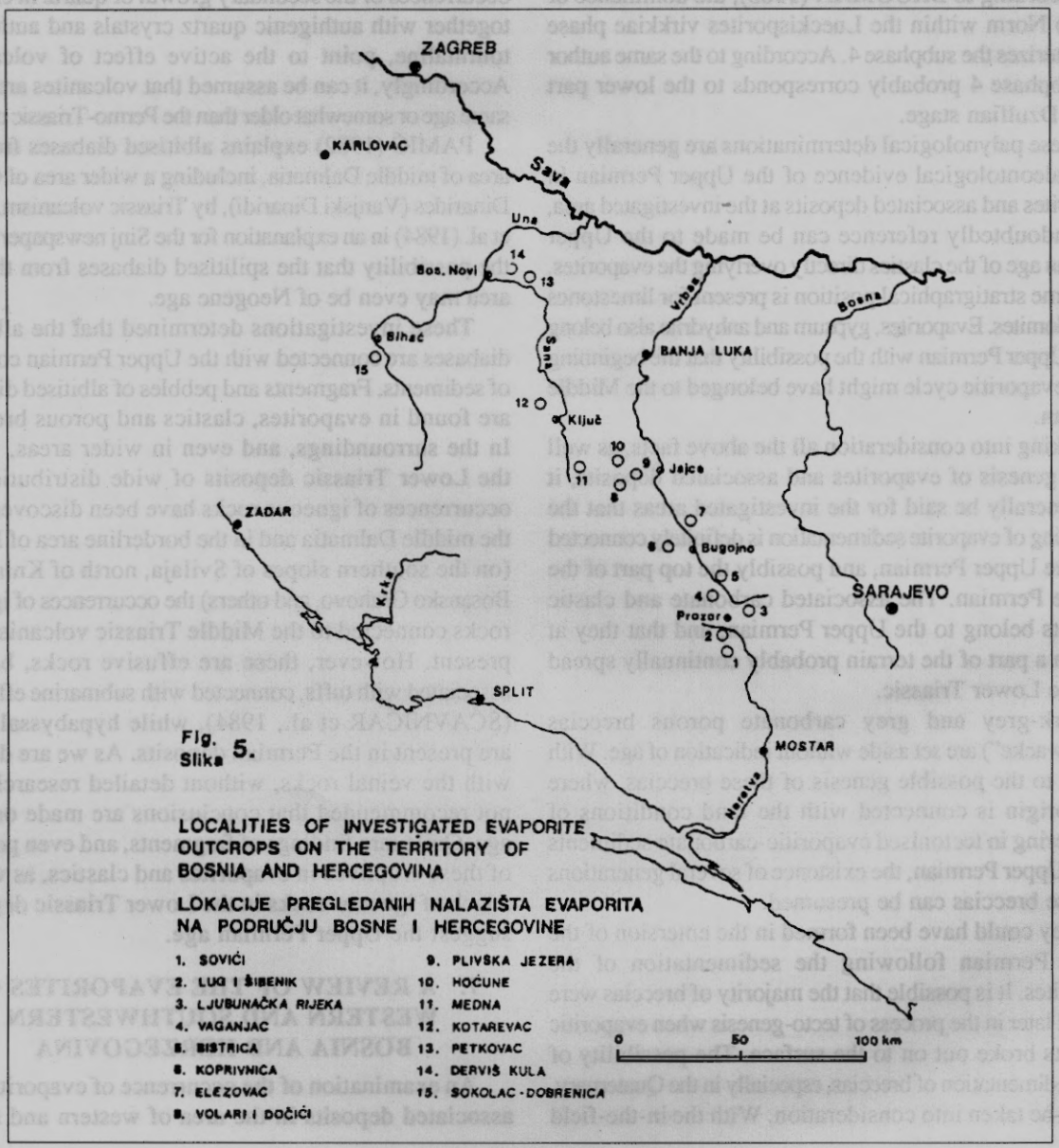


Fig. 5.
Slika

LOCALITIES OF INVESTIGATED EVAPORITE OUTCROPS ON THE TERRITORY OF BOSNIA AND HERCEGOVINA

LOKACIJE PREGLEDANIH NALAZIŠTA EVAPORITA NA PODRUČJU BOSNE I HERCEGOVINE

1. SOVIĆI
2. LUG I ŠIBENIK
3. LJUBUNAČKA RIJEKA
4. VAGANJAC
5. BISTRICA
6. KOPRIVNICA
7. ELEZOVAC
8. VOLARI I DOČIĆI
9. PLIVSKA JEZERA
10. HOĆUNE
11. MEDNA
12. KOTAREVAC
13. PETKOVAC
14. DERVIŠ KULA
15. SOKOLAC - DOBRENICA

in the evaporites.

8. CONCLUSION

The investigated evaporites and associated deposits consist of gypsum and anhydrites on which, in a normal sequence, carbonate and clastic deposits are found. Carbonate rocks are represented by dolomites, limestones and carbonate porous breccias ("rauhwacke") and clastics are represented by pelites, siltstones and sandstones, and very rarely by conglomerates. Apart from these sediments frequently there are small occurrences of altered albitised diabases. In the gypsum and anhydrite intercalations and laminae of dolomicrytes and scattered grains of carbonates are regularly present, while sinsedimentary occurrences of clastics in evaporites are very rare. Gypsum was formed by hydratisation of anhydrites in the surface conditions.

These deposits, although facially different, make up a unique complex which is structurally and tectonically separate from Mesozoic and Older Paleogene deposits, while the Neogene and somewhere Upper Eocene ("Promina deposits") sediments overlie them in transgressive contact, which was lately disturbed by tectonics and diapirism.

The evaporitic complex of deposits has been attributed to various ages, from the Upper-Permian to Cretaceous, although without paleontological documentation. With these investigations on the basis of palynological analyses the Upper Permian age of these deposits was determined. In agreement with this are the occasionally preserved superpositional relations with Lower Triassic (Seiser level), the petrographic investigation, and the isotopic analysis of sulphur from the evaporites.

For the carbonate porous breccias ("rauhwacke") it was determined that there are several generations; Permian, Pre-Neogene and Quaternary, which is in agreement with their genesis and position on the site.

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PLATE - TABLA I.

Enlargements 1000 x, fig.4 750 x.

1. Spore indet. Site Osredci - Novakovići.
2. Spore indet. Site Osredci - Novakovići.
3. *Potonieisporites* sp. Site Suhač.
4. *Nuskoisporites dulhuntyi* POTONIÉ & KLAUS, 1954. Site Osredci - Novakovići.
5. *Perisaccus granulatus* KLAUS, 1963. Site Suhač.
6. *Falcisporites zapfei* (POTONIÉ & KLAUS, 1954) LESCHIK, 1956. Site Suhač.
7. *Klausipollenites schaubergeri* (POTONIÉ & KLAUS, 1954) JANSONIUS,1962. Site Osredci - Novakovići.
8. *Vesicaspora schemeli* KLAUS, 1963. Site Osredci - Novakovići.
9. *Paravesicaspora splendens* KLAUS, 1963. Site Osredci - Novakovići.
10. *Platisaccus papilionis* POTONIÉ & KLAUS, 1959. Site Suhač.
11. *Illinites pemphicus* KLAUS, 1963. Site Suhač.


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PLATE - TABLA II.

Enlargements 1000 x, fig. 5 750 x, fig. 9 660 x.

1. *Illinites* sp. Site Suhač.
2. *Jugasporites delasaucei* (POTONIÉ & KLAUS, 1954) LESCHIK, 1956. Site Osredci - Novakovići.
3. *Jugasporites perspicuus* LESCHIK, 1956. Site Osredci - Novakovići.
4. *Limitisporites moersensis* (GREBE, 1957), KLAUS, 1963. Site Suhač.
5. *Limitisporites* sp. Site Suhač.
6. *Gardenasporites heisseli* KLAUS, 1963. Site Suhač.
7. *Gardenasporites moroderi* KLAUS, 1963. Site Suhač.
8. *Gardenasporites leonardii* KLAUS, 1963. Site Suhač.
9. *Gigantosporites aletoides* KLAUS, 1963. Site Suhač.
10. *Corisaccites alutas* VENKATACHALA & KAR, 1956. Site Suhač.
11. *Lueckisporites virkkiae* POTONIÉ & KLAUS, 1954 (Norm Aa VISSCHER,1971). Site Suhač.

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Gornjopermski evaporiti i prateće stijene Dalmacije i graničnog područja Like i Bosne

A. Šušnjara, K. Sakač, B. Jelen i A. Gabrić

Gornjopermski evaporiti i prateće naslage detaljno su istraživani u sjevernoj i srednjoj Dalmaciji, te graničnom području Like i Bosne. Sastoje se od evaporita, karbonatnih i klastičnih naslaga s kojima su povezane mnogobrojne manje pojave izmijenjenih albitiziranih dijabaza. Evaporiti su predstavljeni gipsom i anhidritom. Karbonati su dolomiti, vapnenci i karbonatne šupljikave breče (tzv. "rauhwacke"). Klastiti su peliti, siltiti i pješčenjaci, ili su vrlo rijetko konglomerati.

Evaporiti su uslojeni i vrlo intenzivno borani. Boje su tamnosive do svjetlosive i bijele. Redovito sadrže leće, proslojke i lamine glinovite komponente, a prisutna je i organska supstancija s piritom. Zbog izmjene sivih, svjetlosivih i bijelih proslojaka, gips je često trakaste teksture. S karakterističnom fibroznom strukturom kristaliziran je krupnozrnasto do sitnozrnasto. U površinskom dijelu (do dubine 20-40 m) nalazi se gips, a dublje postupno prelazi u anhidrit. U istraživanim terenima baza evaporita nije otkrivena.

Dolomiti se izmjenjuju s evaporitima ili se nalaze kao ulošci u vapnencima. Boja im je pepeljasto siva do crna. Pripadaju ranodijagenetskim kriptokristalastim dolomitima (dolomikritima). Redovito sadrže organsku supstanciju, a ponekad i sitne kristaliće autigenog kvarca. Vapnenci se također odlikuju dobrom uslojenošću. Mjestimice su laminirani. Boja im je siva, tamnosiva ili crna od primjesa bituminozne supstancije. Često su ispresijecani brojnim bijelim kalcitnim žilicama. Pripadaju mikritima. Rijetko su zahvaćeni dolomitizacijom. Mjestimice sadrže autigeni kvarc. U području sela Glavice kod Sinja i Umljanovića kod Drniša, u vapnencima se nalaze kristalići fluorita.

Karbonatne šupljikave breče "rauhwacke" vezane su uz evaporitni kompleks naslaga. Karakteriziraju ih brojne male šupljine često ravnih ploha ili sustava nepravilno oblikovanih kanalića. Ponekad izgledaju poput šljake. U sitnozrnastoj kalcitnoj osnovi često spužvastog do saćastog rasporeda sličnog sedri, nalaze se fragmenti gornjopermskih vapnenaca i dolomita, a rijetko gornjopermskih klastita, gipsa i eruptivnih stijena. Fragmenti su uglavnom angularni, rijetko i subzaobljeni. Breče su nesortirane, masivne - neuslojene. Boje su smeđaste ili tamnosive.

Klastiti su pretežno crveni, a često se izmjenjuju sa sivim i zelenkastosivim, dok su znatno rjeđi smeđesivi i crni. Najčešće su dobro uslojeni. U klastitima su dominantni peliti. S povećanjem krupnoće zrna klastita opada njihovo učešće, tako da su konglomerati zabilježeni tek kao manje pojave na nekoliko lokaliteta. Peliti uz osnovnu komponentu minerala glina; ilita, montmorilonita, kaolinita i hidromuskovita, redovito sadrže još i kalcit, klorit, muskovit, feldspat i sitna zrna kvarca. Kod pelita često je izražena finolističava cjepivost paralelne slojevitosti. Peliti često pripadaju karbonatnim šejlovima.

U siltitima, a naročito pješčenjacima, opada sadržaj glinovite komponente, a raste učešće siltno-psamitnog terigenog detritusa: kvarca, feldspata, muskovita, klorita i čestica stijena. Pješčenjaci imaju visok sadržaj kvarca koji obično prelazi 75% od ukupno prisutnog detritusa. Dominantan tip cementa je kemogeni kvarcni cement, dok je matriks detritičnog porijekla rjeđi. Pješčenjaci su zastupljeni tipovima grauvaka (kvarcnih, feldspatskih i tinjčastih), subarkoza (kvarcnih i tinjčastih), te kvarcarenita i kvarclitoarenita.

Eruptivne stijene, većinom izmjenjeni albitizirani dijabazi, nalaze se na niz mjesta u sklopu evaporitnog kompleksa naslaga. Redovito su to mala tijela, često morfološki istaknutog i čunjastog oblika.

Razvoj evaporita i pratećih stijena vrlo je sličan na

PLATE - TABLA III.

Enlargements 1000 x.

1. *Lueckisporites virkkiae* POTONIÉ & KLAUS, 1954 (Norm Ab VISSCHER, 1971). Site Osredci - Novakovići.
2. *Lueckisporites virkkiae* POTONIÉ & KLAUS, 1954 (Norm Ac VISSCHER, 1971). Site Osredci - Novakovići.
3. *Lueckisporites virkkiae* POTONIÉ & KLAUS, 1954. Site Suhač.
4. *Lueckisporites* sp. 1. Site Suhač.
5. *Lueckisporites* sp. 2. Site Osredci - Novakovići.
6. *Lunatisporites ortisei* (KLAUS, 1963) BRUGMAN, 1983 (unpubl.). Site Suhač.
7. *Lunatisporites alatus* (KLAUS, 1963) BRUGMAN, 1983 (unpubl.) Site Suhač.
8. *Striatites jacobii* JANSONIUS, 1962. Site Osredci - Novakovići.
9. *Striatites* sp. Site Osredci - Novakovići.
10. *Ephedripites primus* KLAUS, 1963. Site Suhač.
11. *Cycadopites* sp. Site Suhač.

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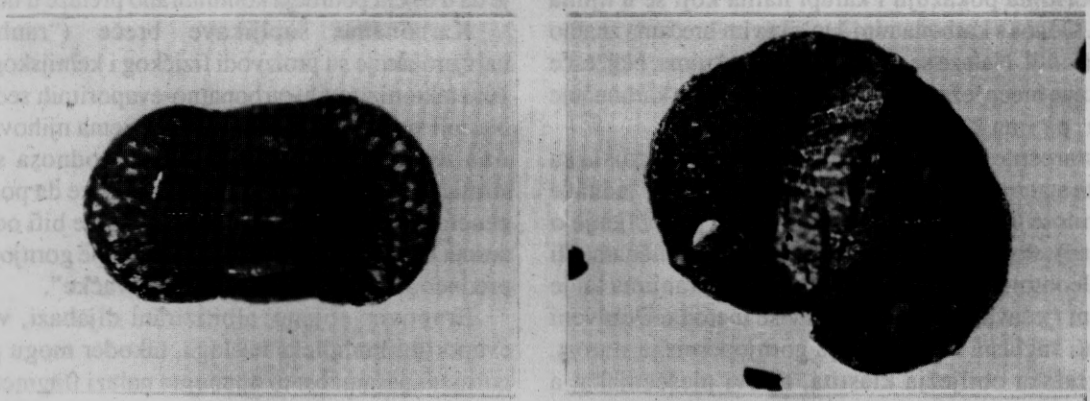

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čitavom istraživanom području. Nalaze se uglavnom u nižim dijelovima terena, u krškim poljima i dubokim dolinama. Povezani su s labilnim tektonskim zonama, kompliciranim strukturno-tektonskim odnosima i dijapirskim utiskivanjima.

Ove naslage, premda facijesno raznolike, jedinstvena su cjelina. Strukturno i tektonski izdvojeni su od mezozojskih i paleogenskih naslaga. Neogenski sedimenti izravno leže na evaporitnom kompleksu naslaga s izraženom kutnom i erozijskom diskordancijom. Vjerojatno su i Promina naslage bile primarno, barem mjestimice transgresivne na evaporitnom kompleksu, kao u Petrovu polju i Kosovu polju. Na to upućuje odnos geoloških granica i morfologije terena. Osim toga, u sastavu bazalnih konglomerata Promina naslaga kod Drniša, uz ostale, nalaze se i mnogobrojne valutice gornjopermskih pješčenjaka. Međutim, primarni kontakti gornjopermskih naslaga s neogenskim sedimentima, a osobito s Promina naslagama su poremećeni rasjedima i dijapirskim kretanjima evaporita i pratećih naslaga.

Superpozicijski slijed i međusobni odnosi litoloških članova evaporitnog kompleksa uglavnom je istovjetan na čitavom istraživanom području. Najstariji su evaporiti, a na njima neposredno leže karbonatni i klastični sedimenti koji su vjerojatno taloženi istodobno, ali u različitim uvjetima. Mjestimice, u vršnom dijelu evaporitne serije, ima višestrukih izmjena evaporita s karbonatima, vrlo rijetko i s klastitima. Sinsedimentacijski dolomikriti redovita su pojava u evaporitima. Povezanost klastita s evaporitima pokazuju i kalupi halita koji se u njima nalaze. Odnos s karbonatnim šupljikavim brečama znatno je zamršeniji. Nalaze se u različitim položajima. Najčešće šupljikave breče leže izravno na gipsu, ali i uz karbonatne stijene, pa i na klastitima.

O starosti evaporita i pratećih naslaga postojala su različita stanovišta. Svrstavani su u stratigrafske jedinice od permotrijasa do krede Prevladavalo je mišljenje o permotrijaskoj i donjotrijaskoj starosti sedimenata, ali bez paleontoloških dokaza. Našim istraživanjima taj je problem rješavan kompleksno s više metoda. Dobiveni rezultati suglasni su i dokazuju gornjopermsku starost. Petrografska obilježja klastita, tipovi pješčenjaka, a osobito sastav i karakteristike teških minerala iz klastita upućuju na vezu s najvišim nivoima "gredenskog" facijesa iz ostalih područja zapadnog dijela Dinarida (IVANOVIĆ et al., 1971). Izotopne analize sumpora iz gipsa i anhidrita dale su ujednačene vrijednosti od 9,07 do 13,66, što također upućuje na gornjopermsku pripadnost.

Primarni odnosi evaporitnog kompleksa naslaga s donjotrijaskim sedimentima sajskog nivoa vrlo rijetko su očuvani u istraživanim terenima. Tako na nekoliko mjesta u Petrovu polju i Kosovu polju na karbonatnim i klastičnim naslagama iz evaporitnog kompleksa izravno leže sajski sedimenti. Slični odnosi zapaženi su u Gornjoj Suvaji nedaleko Srba.

Međutim, najvrijednije dokaze za stratigrafsku pripadnost evaporitnog kompleksa naslaga pokazale su palinološke analize kojima je prvi put precizno utvrđena njihova starost. U klastitima, koji leže neposredno na evaporitima kod Sinja, nađen je bogat i dobro očuvan palinološki materijal. Asocijacija *Corisaccites alutas*, *Potonieisporites* sp., *Lueckisporites virkkiae*, *Klausipollenites schaubergeri*, *Jugasporites delasaucei*, *Lunatisporites* sp. div., *Nuskoisporites dulhuntyi*, *Perisaccus granulatus*, *Gardenasporites heisseli*, *Gigantosporites aletoides*, *Strotersporites* sp., prema studiji BRUGMANA (1983) dokazan je donji dio gornjeg perma (u trodjelnoj podjeli perma). U klastitima iz šire okolice Srba (Osredci-Novakovići) određena asocijacija *Lueckisporites virkkiae* Norm Aa, *Lueckisporites virkkiae* Norm Ab (dominanta), *Lueckisporites virkkiae* Norm Ac, *Klausipollenites schaubergeri*, *Jugasporites delasaucei*, *Lunatisporites* sp. div., *Nuskoisporites dulhuntyi*, *Strotersporites* sp., isto potvrđuje gornji perm. Prema studiji BRUGMANA (1983) dominacija Norm Ab u okviru Lueckisporites virkkiae faze karakterizira subfazu 4 kojoj vjerojatno odgovara donji dio dzulfijskog kata.

U klastitima Vrličkog polja palinomorfe su lošije očuvane, a određene su kao forme cf. *Lueckisporites* i cf. *Gigantosporites*, što upućuje na gornji perm. Prisutan je polen i u Kosovu polju te kod Kulen Vakufa, ali zbog loše očuvanosti nije ga bilo moguće odrediti.

Na osnovi iznesenih činjenica može se reći za istraživano područje da je taloženje evaporita sigurno vezano za gornji perm, a moguće je da je započelo u gornjem dijelu srednjeg perma. Prateće karbonatne i klastične naslage pripadaju gornjem permu, a moguće je da u dijelu područja kontinuirano prelaze u donji trijas.

Karbonatne šupljikave breče ("rauhwacke") najvjerojatnije su proizvodi fizičkog i kemijskog trošenja jako tektoniziranih karbonatno-evaporitnih sedimenata. Nastali su u kopnenim uvjetima. Prema njihovoj genezi i na temelju utvrđenih položaja i odnosa s drugim stratigrafskim članovima, zaključuje se da postoji više generacija ovih breča. Starost im može biti od gornjeg perma do kvartara. Sigurno su utvrđene gornjopermske, predneogenske i kvartarne "rauhwacke".

Eruptivne stijene, albitizirani dijabazi, vezani uz evaporitni kompleks naslaga, također mogu pripadati gornjem permu. Na to upućuju i nalazi fragmenata ovih stijena u gornjopermskim klastitima.

Na osnovi tako utvrđenih činjenica o stratigrafskoj pripadnosti evaporitnog kompleksa naslaga bilo je moguće načiniti više značajnijih izmjena u dosadašnjim interpretacijama geoloških odnosa prikazanih na pojedinim listovima Osnovne geološke karte SFRJ 1:100 000. Ovo se osobito odnosi na širu okolicu Srba i područje duž gornjeg toka rijeke Une (Sl. 3).

Pregledana su također i brojna nalazišta evaporita u zapadnoj Bosni i Hercegovini. Utvrđeno je da se oni nalaze u sličnim strukturnim odnosima i razvoju kao u naprijed opisanim područjima. Zaključuje se da i oni također vjerojatno pripadaju gornjem permu.

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