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SUBSURFACE SPREADING AND FACIES CHARACTERISTICS OF MIDDLE PLEISTOCENE DEPOSITS BETWEEN ZAPREŠIĆ AND SAMOBOR

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Key words: Middle Pleistocene, Holocene, facies, subsurface mapping, Zagreb region

Ključne riječi: Srednjopleistocenske taložine, holocenske taložine, facijes, dubinsko kartiranje, okolica Zagreba

The study of subsurface Middle Pleistocene deposits was performed using subsurface mapping methods. These sediments consist of unsorted gravels of lithoarenite pebbles mixed with sand and silt. To the west of the confluence of Krapina with Sava they are unconformable upon Upper Pontian layers, filling up a furrow-like depression in the palaeo-relief. These deposits form a plano-convex shaped lenticular body, produced by the transport of detritus from the nearby dry land areas into a shallow sweet water environment.

Deposition occurred during the Mindel/Riss interglacial stage, and one part of the Riss glacial, before cooling and draught had reached their peak. The swamps of the contemporaneous periglacial belt were then drastically reduced in size or dried up. Such conditions probably persisted until the end of Pleistocene, as the Würm glacial is distinguished by the coldest, driest weather throughout the Quaternary. A sudden thaw and tectonic movements in the Holocene enabled intensive fluvial transport and deposition of well graded gravels, with rounded pebbles (primarily composed of limestone), which directly covered either Pontian or Middle Pleistocene deposits. In comparison with older clastics, they represent a different mode of sedimentation and more distant source for the greatest mass of detritus.

Metodama dubinskog kartiranja proučene su potpovršinski rasprostranjene srednjopleistocenske naslage. To su nesortirani šljunci s valuticama litoarenita i pjeskovito-prašinski sedimenti koji zapadno od utoka Krapine u Savu diskordantno nalježu na gomjopontske naslage ispunjavajući žljebasto udubljenje paleoreljeva. U suglasju s tim, njihovo tijelo je približno oblika plankonveksne leće. Nastali su snažanjem detritusa u plitku slatkovodnu sredinu s obližnjih kopnenih predjela tijekom mindel/riss interglacijala i dijela riss glacijala prije nego su zahlađenje i suša dosegli svoj maksimum. Tada se močvare ondašnjeg periglacialnog pojasa drastično smanjuju ili presušuju što vjerojatno traje do kraja pleistocena jer se upravo würm odlikovao najvećim hladnoćama i suhoćom u kvartaru uopće. Naglim zatopljenjem i tektonskim pokretima u holocenu omogućen je intenzivan fluvijalan donos i odlaganje dobro sortiranih šljunaka sa zaobljenim valuticama dominantno vapnenačkog sastava prekrivajući izravno ili pontske ili srednjopleistocenske naslage. U odnosu na starije klastite, ovi se odlikuju drugim mehanizmom taloženja i udaljenijim izvorijem najveće mase detritusa.

1. INTRODUCTION AND REVIEW OF RESULTS ACHIEVED BY EXPLORATIONS UNTIL PRESENT TIME

Complex exploration of the HEPS Podsused site, aimed at a definite assessment of adequacy of the proposed position was performed in 1988. This research assembled and elaborated the known data on Neogene and Quaternary sediments. This paper will set out new ideas regarding subsurface spreading, lithological features, stratigraphic position and conditions of genesis of the Middle Pleistocene deposits. During current research subsurface mapping techniques were used, which resulted in the production of a number of graphic presentations, maps as well as correlation sections. Only correlation sections have been used as illustrations in this paper.

The explored area is located along the northern bank of the Sava river, 1100 m due west of its confluence with the Krapina river (Fig. 1a). The ground elevation varies between 123 and 125.5 m. Beside the arable land and meadows, there are, due to luxuriant vegetation, some impenetrable areas. During rainy seasons these become wetlands and mudlands. There are no outcrops of older Quaternary sediments in closer vicinity of location, so that direct information about these depends

solely on drilling.

Papers concerning the Quaternary sediments within the area between Zaprešić and Samobor are meagre and scarce. Certain conceptions on Pleistocene sediments are almost one hundred years old, followed, after a 60-years' interval, by a somewhat greater number of papers. One of first authors, GORJANOVIĆ-KRAMBERGER (1908) separated the Diluvium build-ups into two groups: slope loams and the valley Diluvium. The latter is predominantly yellow and grey coloured, and in part represents sediments of a former swamp, similar to a lake.

The swamp covered the Sava plain, and can be dated from as early as Upper Pliocene. BORČIĆ et al., (1968) have found that the water-bearing gravels and sands overlie a brown, gravelly clay, and an older, grey-blue clay comparable to Pleistocene and Upper Pliocene deposits.

Through morphometric analysis, performed by PRELOGOVIĆ (1969; 1970), with the aid of the second order isolong map, the relief formed after the deposition of Plio-pleistocene sediments (which is very similar to the recent relief) has been reconstructed. While studying the mineralogical - petrographical composition of the Sava river deposits, CRNKOVIĆ & BUŠIĆ, (1970)

noticed that from Krško polje, through Zaprešić and Rakitje to Jarun and Novo Čiče, the composition of cobbles changes from markedly dolomite-limestone to carbonate, with a large proportion of quartz and quartz clastics.

The most comprehensive review of Quaternary sediments in the Sava river valley near Samobor is that by KOVAČEVIĆ & CAPAR (1972). Among other things, they conclude that the area due north of Nedelja, towards Sava, is filled with substantial deposits of detritus, whereby the 10 to 15 m thick layer of gravel and sand forms only their shallower part. Clayey deposits mixed with gravel achieve locally thicknesses of more than 45 m, as opposed to places where marl occurs 10 to 15 m beneath the surface. This was also established by ŠIKIĆ & BASCH (1975), and ŠIKIĆ et al. (1979). They stated that the average thickness of the alluvial gravelly-sandy layer in Krško polje and Brežičko-samoborsko polje is appr. 10 to 12 m, or even more in places, adding however that its base consists of Miocene and Pliocene sediments.

The more detailed chronostratigraphic division of Quaternary sediments, to the west of Podsused, can be found in the paper written by ČAKARUN et al. (1987). A differentiation has been made between Upper Pleistocene-Holocene, Middle Pleistocene and Upper Pliocene clastics, based on their varying granulometric characteristics. VELIĆ (1989) described the characteristics of subsurface Middle Pleistocene clastic bodies within the Sava valley from Bregana to Podsused.

2. PRELIMINARY STUDIES

The contents and extent of preliminary studies was planned so as to provide the greatest variation of geological-geomechanical data. In this sense, geophysical measurements were performed (including well-logging), as well as drilling, core logging and the laboratory analysis of samples. Through the correlation and interpretation of all the data new ideas about the development of Quaternary clastics have been achieved.

Vertical electrical sounding as well as profiling and shallow refraction techniques were the geophysical methods used in the present study. During exploration, wells were measured for natural and induced radioactivity, i.e. γ and $\gamma\gamma$ curves were plotted (Fig. 2, curves to the left and right of the lithological columns). From the more successful density logs (synonymous with the induced radioactivity measurement) it can be observed that they satisfactorily reflect the density contrasts of deposits.

Eighteen exploration wells were drilled within an area of appr. 7.5 ha, reaching to depths from 15 to 60.2 m (Fig. 1a). Cores were obtained from all of wells using a wide (10 cm) single core bit. The cores were logged during drilling and the following samples were collected:

- gravel and gravelly coarse-grained sand for petrographic analyses,
- sand for optical analyses of mineral composition, using

the polarisation microscope,

- silty-clays for X-ray diffraction,
- silty-sandy sediments for micropaleontological determination and
- various types of sediments for granulometry.

3. LITHOLOGY AND STRATIGRAPHY

For the purposes of this study the most important wells were the deepest ones - (B-3, B-11 and B-12), which represent Pontian, Pleistocene and Holocene sediments, reaching depths of 54.5, to 60.2 m.

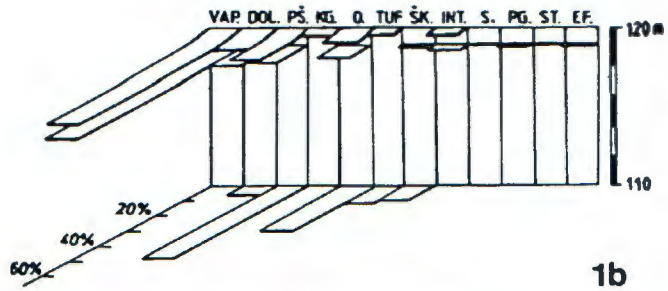
3.1. UPPER PONTIAN MEMBER

In all exploration wells, except B-3, a 4.4 to 42.7 m thick interval of the Upper Pontian sediments was encountered. They occur in decimetre or centimetre-sized beds of clayey silt and fine-grained, or, more rarely, medium-grained sand of grey, grey-brown and grey-bluish colour. Thicker strata, built up of a single granulometric fraction are scarce. In the course of analysis, broken fossil Lamellibranchiata were noted. The natural radioactivity and granulometric diagrams (Figs. 2 and 3) point to a tendency of gradual increase of the clay portion with depth, mostly from 30 m below the ground surface.

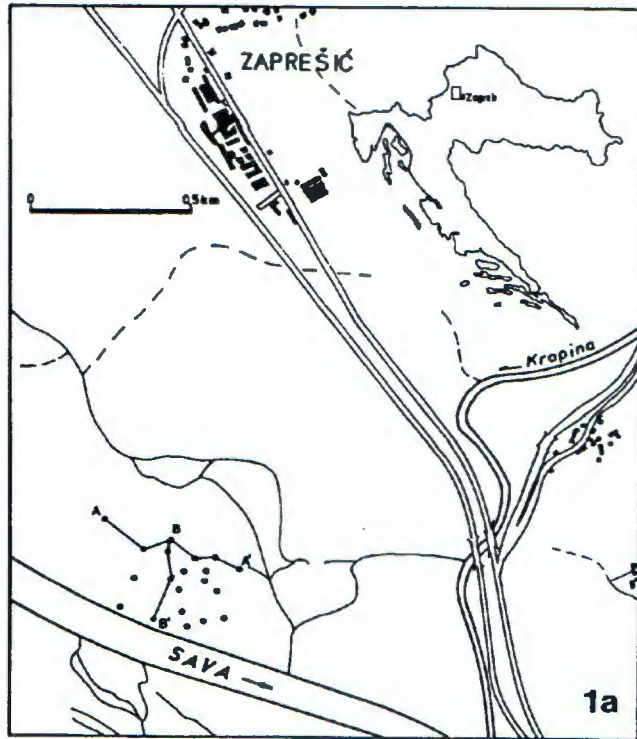
All samples of sand, silt and clay were collected in order to determine the mineral composition of the Upper Pontian chronostratigraphic level (Fig. 1c). Quartz is the primary component (20-55%), followed by plagioclases (12-20%), micas (muscovite/sericite 12-24%), carbonates (with an evident predomination of dolomite 13-33%) and chlorite (3-9%). Heavy minerals were qualitatively determined including epidote, zoisite, garnet, amphibole, titanite, disthene, apatite, zircon and opaque minerals. Identical findings, i.e. that the quartz is predominant in the light and the epidote in the heavy mineral fraction of sands, were published by ŠIKIĆ et al. (1979), as well as An. ŠIMUNIĆ & Al. ŠIMUNIĆ (1987).

The Upper Pontian age of these fine-grained clastics has been reliably documented based on the abundant ostracod fauna, characteristic for the caspian-brackish environment. The following species were determined: (*Hungarocypris* cf. *pannonica* (ZALANYI), *Amplocypris* *reticulata* (ZALANYI), *Candona* (*Caspiocypris*) *labiata* (ZALANYI), *C. (Caspiocypris) alta* (ZALANYI), *C. (Caspiocypris) sp.*, *C. (Camptocypris) balcanica* (ZALANYI), *C. (Camptocypris) cf. hungarica* (ZALANYI), *C. (Camptocypris) sp.*, *C. (Lineocypris) branka* KOSTIĆ, *C. (Lineocypris) trapezoidea* SOKAČ, *C. (Lineocypris) sp.*, *C. (Pontoniella) sp.*, *Bacunella* *dorsoarcuata* (ZALANYI), *Leptocythere sp.*, *Hemicytheria pejinovicensis* (ZALANYI), *Cyprideis* *triangulata* KRSTIĆ and *C. seminulum* (REUSS).

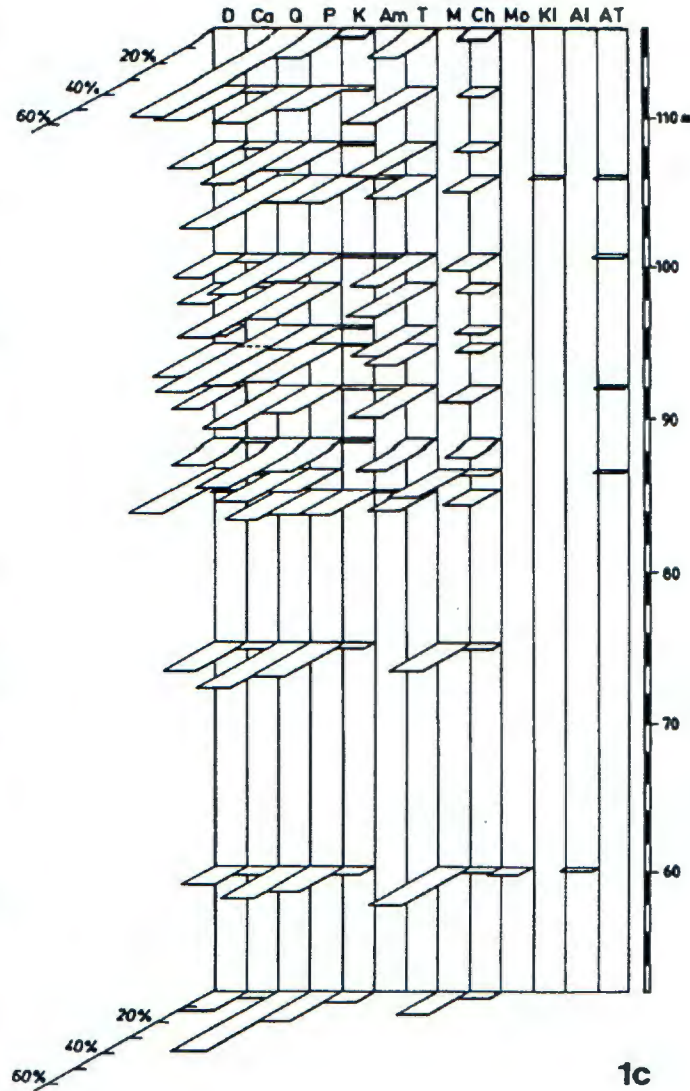
Finishing with description of Upper Pontian Member, it is particularly significant to stress the



1b



1a



1c

LEGENDA: LEGEND:

- | | |
|-----|--|
| VAP | vapnenci limestones |
| DOL | dolomiti dolomites |
| PŠ | pješčnjaci sandstones |
| KG | konglomerati conglomerates |
| Q | kvarcit, polikrist. kvarc i rožnac quartzite, polycrystal q. and chert |
| TUF | efuzivi i tuf extrusive rocks and tuff |
| ŠK | kvarc-tinčasti i kristalasti škriljanci schists |
| INT | kiselji intruzivi acid intrusive rocks |
| S | slješt slate |
| PG | pegmatiti pegmatites |
| ST | silit siltstone |
| EF | kvarc keratofiri i kis. efuzivi acid extrusive rocks |
| D | dolomit dolomite |
| Ca | kalcit calcite |
| Q | kvarc quartz |
| P | plagioklas plagioclase |
| K | kalijski feldspat K-feldspar |
| Am | amfibol amphibole |
| T | tinjci micas |
| M | muskovit muscovite |
| Ch | ktorit chlorite |
| Mo | montmorilonit montmorillonite |
| KI | kaolinit kaolinite |
| Al | alofan allophane |
| AT | amorfnu tvar amorphous matter |
| A° | istražne bušotine i korelacijski profili exploration wells and correlation sections |

Sl. Fig. 1

characteristics of its youngest, top part. It is regularly made up of the 20 to 50 cm thick beds of, fine-grained silty sand, with a markedly "gaudy" look, apparently due to irregular spotting in yellowish-brownish shades. Only the sample from this interval contains, in addition to the other minerals mentioned above, very poorly crystallized goethite and amorphous iron hydroxide. Their occurrence points to the existence of a weathering crust, because their genesis is tied to the oxidation/diagenesis of ferrous minerals.

3.2. MIDDLE PLEISTOCENE MEMBER

The Upper Pontian sediments were encountered predominantly some 10 m from the surface. Drilling of the B-3 exploration well signified however, an occurrence deviating from the usual lithological succession and thereby also the chronostratigraphic sequence up to that time. Instead of fine-grained grey sediments, the core bit recovered Middle Pleistocene gravels, sands, silts and clays, in an interval of 9.0 to 54.5 m, namely to the bottom of the well. Based primarily upon the core determination, as well as the grain composition (Figs. 2 and 3), it is possible to separate eight levels in them. In decreasing stratigraphic order these are:

- 6.3 m of poorly cemented brownish sand and gravel,
- 2.7 m of soapy, grey and grey-brown clay with impressed cobbles of various sizes,
- 10.6 m of an ungraded mixture of gravel, sand and silt, poorly lithified,
- 0.6 m thick deep-grey silty clay, with very rare cobbles and thin interbeds of sand,
- a 12.2 m succession of fine-grained sand, silt and clay in shades of grey, with sporadic cobbles and brittle fossil *Lamellibranchiata*,
- 7.1 m of light-grey gravel, fine to medium-grained sand and some silt,
- a 3.9 m thick grey-greenish clayey silt, with some gravel near the base,
- a 2.1 m thick yellowish-brown silty clay.

Due to the manner in which the granulometric probes were taken, the described changes are not fully expressed in the analysis for B-3 in Fig. 3.

According to the petrographical treatment of the sample from the top of Middle Pleistocene deposits, it consists of poorly sorted, gravelly, coarse-grained sands of sandstone composition. There are no limestone cobbles at all (Fig. 1b). Sandstone cobbles predominate (47.5%), followed by quartzite and polycrystal quartz (28.8%). Cobbles of extrusive rocks and/or tuffs (10.2%), schists (8.5%) and dolomite (5%) form the minor constituents, as determined by R. MUTIĆ (ČAKARUN et al., 1987).

Results obtained from the micropaleontological analysis of a deep brown sandy-clayey silt sample from well B-12 at a depth of 18.0 to 18.2 m indicated a Middle Pleistocene age. Beside Mollusca, charophyte oogonia and remains of encrusted roots (*Rhizosolenia*), the

following ostracod species were observed: *Candona neglecta* SARS, *C. compressa* (KOCH) BRADY, *Cyclocypris ovum* (JURINE), *C. leavis* (O. F. MÜLLER) and *Scottia tumida* (JONES). Of these, *Scottia tumida* (JONES) is the best biostratigraphic indicator, as it is an abundant widespread species in Middle Pleistocene strata of this area (SOKAČ, 1978).

The lateral extent of these sediments is very limited, which can be plainly seen on sections A-A' and B-B' (Figs. 2 and 3). Except in the exploration well B-3, which did not reach the substratum, they were only found in wells B-11 and B-12, between intervals of 13.5 to 29.2 m and 9.6 to 22.4 m. The sedimentary body has a geometry similar to a plano-convex lens, appr. 200 m wide and more than 45 m thick.

3.3. HOLOCENE MEMBER

Thick gravels and sandy gravels, varying from 6.6-13.1 m (but most commonly 7.6-9.4 m), were deposited upon the Upper Pontian or Middle Pleistocene deposits, over the whole of the study area (Figs. 2 and 3). Petrographically, these are gravels of limestone composition, and they occur with some pale-yellowish to light-grey sand and silt. The grain size decreases upwards allowing two intervals to be separated (Figs. 2 and 3):

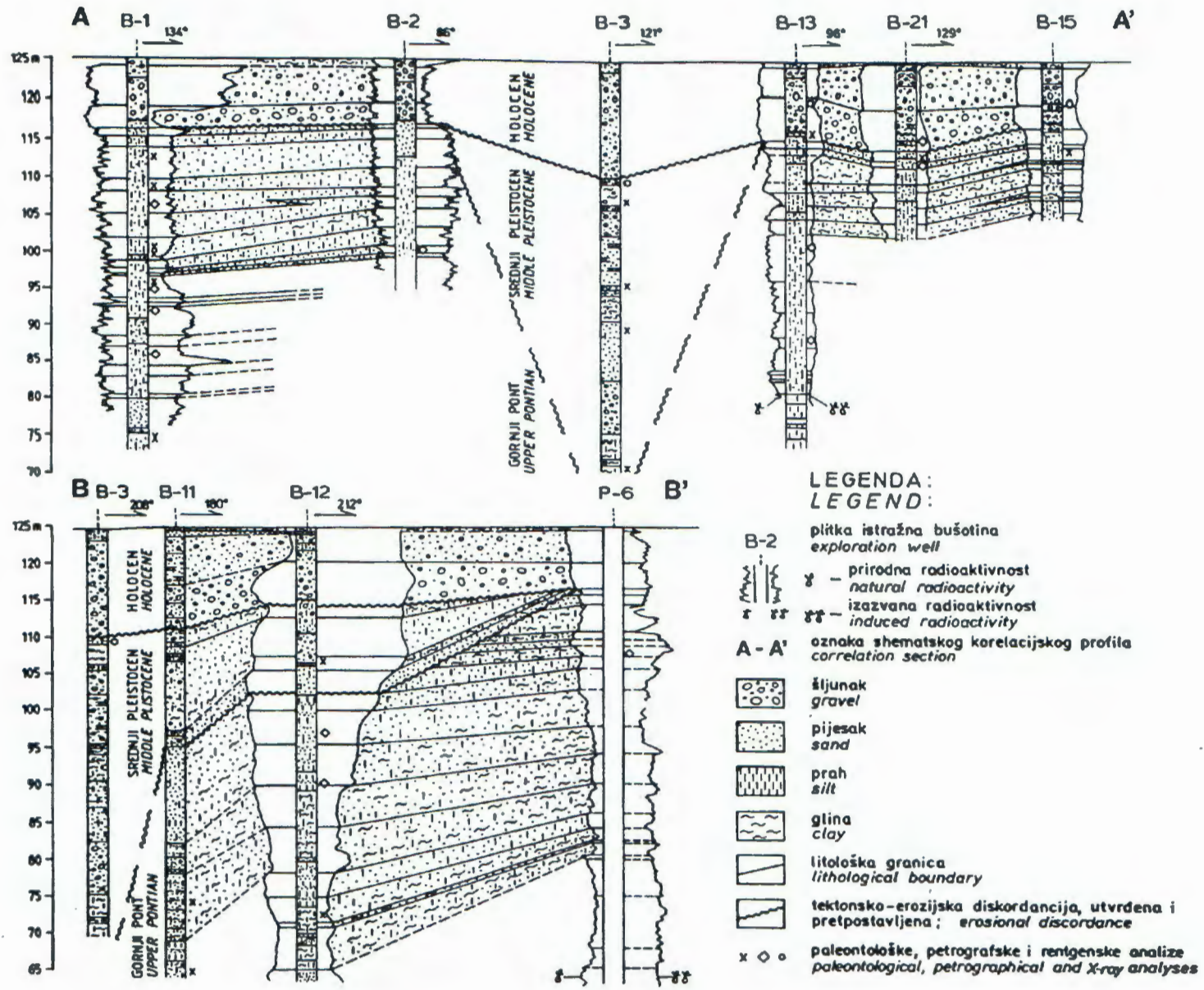
- a lower older interval with coarser gravel cobbles and pebbles and
- an upper, younger unit with finer gravel pebbles, accompanied by sand and silt.

Both intervals are of an almost uniform thickness, although both may thicken or thin locally.

Depending on the granulometric distribution, gravels contain between 57.8 and 70.1% of limestone pebbles, 7.8 to 13.4% of dolomite ones and 8.9 to 16.4% of sandstone (Fig. 1b). Other petrographic types, including quartzite, chert, conglomerates, acid intrusive rocks, extrusive rocks and tuffs, each contribute a few percent and they regularly occur only in the finest fraction - less than 4.15 mm. No fossils were found, conforming with previous research (see ŠIKIĆ et al., 1979). They classified the coarse-grained gravels and sands, in which well rounded carbonate cobbles most commonly occur, into the Pleistocene - Holocene aluvial deposits. ČAKARUN et al., (1987) are somewhat more specific, classifying the near-surface, 7 to 12 m thick, very coarse-grained gravels and sands into the Upper Pleistocene - Holocene.

On the basis of superposition, substratum characteristics, petrographical composition, the Quaternary climate and modes of sedimentation, it can be concluded that the limestone cobbles described above are of Holocene age.

The whole terrain is covered by silty-sandy material, rich in organic matter and light-brown coloured humus. Its thickness varies between 0.3 and 0.8 m.



Sl. Fig. 2

4. THE GENESIS OF MIDDLE PLEISTOCENE SEDIMENTS

Using the field, laboratory and exploration results, it is possible to reconstruct the process of genesis, or lithogenesis of Middle Pleistocene and Holocene sediments. In this sense, we shall continue to state hypotheses about which rocks were the source of detritus, how it was transported to the place of sedimentation, which were the facies and environments of sedimentation, i.e. mechanical, physico-chemical and biological conditions, as well as the shape and size of these Quaternary build-ups.

The base or palaeorelief on which Quaternary deposits unconformably lie consists of Upper Pontian sandy silts. During the depositional hiatus preceding the Middle Pleistocene a weathering crust, 20 to 50 cm thick and yellowish-brown in colour formed on the surface of the Upper Pontian sediments. The presence of poorly crystallized goethite supports this, representing the effects of oxidation in aerobic conditions (FITZPATRICK, 1971). Simultaneously, a relatively high palaeorelief was being formed. Its appearance is in direct connection with the vertical neotectonic movements. Namely, the elaborated terrain lies upon a Neogene horst, delimited by north-west to south-east trending faults about 1,000 m apart (PRELOGOVIĆ, 1969; 1970). This structure fits into the contour of local neotectonic uplifting. The uplifting initiated a period of intensive erosion, during which furrow-like depressions oriented approximately north-east to south-west and with an inclination in the north-east direction were formed. These depressions were the sites of deposition of the Middle Pleistocene gravels, sands and silt, while protecting them from erosion and denudation during the hiatus which lasted until alluvial gravels of limestone composition were deposited during the early Holocene.

In the Middle Pleistocene, probably during the Mindel/Riss interglacial stagnant waters, swamps and/or smaller-size lakes filled up the palaeorelief depressions, primarily as the effect of the increased humidity pluvial belt (MARKOV, 1970). The water bodies continued to exist even in the older Riss, until glacial conditions became extreme. It is possible to elaborate on the climatic conditions which prevailed at this time.

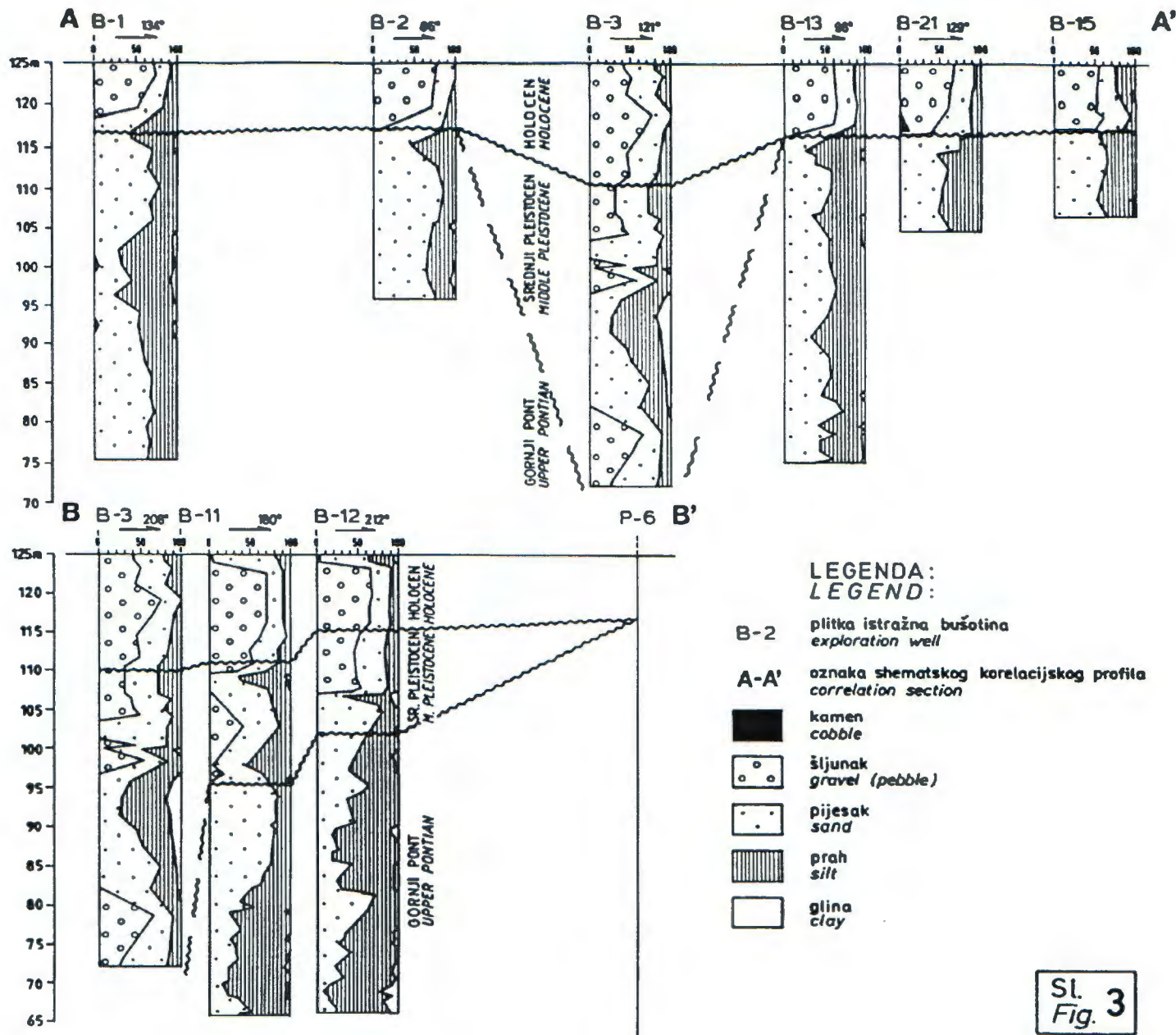
Firstly, the temperature curves of glacial periods are not symmetrical, but asymmetrical (ŠEGOTA, 1966; 1967). The minimum temperatures did not dominate in the middle of the glacial period, but nearer to its end. The relationship between the periods of time of gradual cooling down to the minimum and the sudden warming up is 4:1. This relationship remains the same for all glacial periods. If the present mean annual temperature in Central Europe is taken to be 8°C then it had been 1 to 3°C higher during the Mindel/Riss interglacial, and at the time of the maximum Riss glacial even 11°C lower. In other words, the mean annual temperature during the lower Middle Pleistocene is estimated to have been 9 to 11°C,

falling towards -3 to -2°C towards the end of the period (PECSI, 1963; ŠEGOTA, 1967). Apart from temperature, humidity was also significant in the genesis of Quaternary sediments. According to MARKOV (1970), Zagreb and its environs were, during the Pleistocene, in a periglacial zone, in which the progressive cooling was accompanied by a progressively deepening drought.

The climate as described is reflected in the fossil contents as well. In this sense, it is significant to find the ostracod *Candona neglecta*, which belongs into stenothermal cold forms, being at the same time characteristic for an oligohaline environment (SOKAČ, 1976; 1978). The paleoecological conditions are more clearly indicated when the frequent remains of charophyte oogonia and encrusted rootlets of tiny plants, ("Rhizosolenia" of HILTERMANN, 1952) are taken into account. It can be concluded that this was a shallow, sweet water environment, poor in dissolved salts, which periodically used to dry up. Apart from ostracods, tinier plant species lived on the sandy and silty bottom as well. The oligohaline characteristic may mean an indication that these swamps or lakes had been recharged prevalingly by fresh water.

Further confirmation that the sedimentation of part of these deposits occurred during the cooler, upper Middle Pleistocene is found in the fact that "Rhizosolenia" are built up of sand particles glued together with calcium carbonate, the genesis of which is strongly analogous to that of travertine. The plant, by taking CO₂ out of the dissolved calcium bicarbonate, incites precipitation of calcite. As the solubility of calcite increases with the fall of temperature (KRAUSKOPF, 1985), the frequency of incrustation finds might possibly, for this reason, reflect the quantity of dissolved calcium bicarbonate.

The grain-size distribution, which shows a simultaneous sedimentation of gravels, sands, silts and clays (Fig. 3) is the result of deposition during rapid sub-aqueous sedimentation, after a sudden fall in water energy. During rainy seasons, torrents transporting the detritus into the lake suddenly lost their energy, whereby poorly graded and resedimented material was deposited in the immediate vicinity of the bank. Considering the petrographical composition, the source area had been prevalingly built up of Lower Triassic and Paleozoic clastics, which spread out on neighbouring mountains - Medvednica, Marijagorička brda and Žumberačko gorje. The contact between Upper Pontian and Middle Pleistocene layers is today not marked, among other things, by the brown weathered layer. Coats of iron oxyhydroxide, which gives sediments their yellow-brown colour, were reduced through the action of stagnant waters, accompanied by cooling. The process went on as follows: the gradual decrease of oxygen within the bottom zone activates fermentation processes and acids originating from these reduce iron species. These are processes similar to present-day conditions whereby so called "gley" sediments in continental taigas and steppes are formed (PEREL'MAN 1967; 1975).



Sl. Fig. 3

Through the gradual process of cooling during the Riss period (down to a temperature minimum of -3°C mean annual temperature) this part of the glacial-periglacial belt became markedly dry. Shallow sweet water environments received less and less water, leading locally to drying up. The answer to the question of whether during the 40.000 - years interglacial Riss/Würm period sedimentation had been renewed, should be sought where Pleistocene sediments are thicker than those described here. Namely, where some of the exploration wells drilled due north of Samobor and Nedelja, along the southern bank of the Sava and more than 100m deep did not reach the base of the Quaternary. It is likely that these thicknesses are the effect of either continuous or renewed sedimentation, during the Mindel/Riss and Riss/Würm interglacial and Riss glacial in somewhat deeper and more spacious lakes, or a single lake, connected with zones characterised by constant neotectonic sinking.

The Würm glacial was the coolest period of the Quaternary glaciations, with -4°C of mean annual temperature during its last quarter (ŠEGOTA, 1966; 1967), accompanied with even more marked dryness (MARKOV, 1970). Such climatic characteristics favoured the continuity of nondeposition until the beginning of Holocene, when a sudden warming up occurs, with temperatures comparable with those which prevail today.

The melting of glaciers in Alpine regions, accompanied with some tectonic processes, provided conditions for the resumption of sedimentation, but with essentially different facial characteristics. Due to the river's (Sava) breakthrough of a torrential character, the transported and deposited material was medium - to coarse-grained gravels with well-rounded pebbles of 4 to 45 mm in diameter. The most common pebbles are those of limestone which would stratigraphically correspond to Triassic, Jurassic and, less often, Cretaceous carbonates. They bear cataclastic features, tectonic crushing and breaking and also, quite commonly, diagenetic changes, such as recrystallization and silicification. For the dolomite pebbles it is almost certain that they originated from the Upper Triassic "Hauptdolomite". In comparison with the Middle Pleistocene layers, these represent both a different sedimentation mechanism and source of detritus, which can be mostly considered to be the Alps. Wherever these youngest gravels lie directly upon Pontian layers the brownish weathering crust has been ascertained, pointing to the fact that iron oxihydroxides have not been reduced due to the presence of free-flowing oxygenated waters.

5. SUMMARY OF RESULTS OBTAINED

Along the left bank of the Sava river, 1,100 m due west of its confluence with the Krapina river, upon an area of appr. 7.5 ha, complex geological-geomechanical exploration was carried out, together with the application of geophysical measurements and drilling (with 100% coring). Core samples were collected for use in

petrographic, mineralogical and granulometric analyses, as well as for micropaleontologic treatment.

Three exploration wells, 54.5 to 60.2 m deep, penetrated, Pontian, Pleistocene and Holocene sediments. In the fifteen remaining exploration wells only Pontian and Holocene deposits have been established (Figs. 2 and 3). The Upper Pontian sediments, represented by grey-brownish and grey-blue, thin strata and laminae of clayey silt and fine-grained sand, contained a rich ostracod fauna, allowing chronostratigraphic determinations to be made. In the upper part of these deposits, (yellowish-brown in colour and 20 to 50 cm thick), goethite, among other minerals, established the weathering processes of minerals containing iron in their composition.

The Middle Pleistocene gravels, sands, silts and clays more than 45 m thick can be subdivided into eight characteristic levels. These are intervals of coarser and finer clastics, grey and brown coloured, 2.7 to 12.2 m thick. Their lateral extent is very limited (sections A-A' and B-B' in figs. 2 and 3). They make a body which can be compared to a plano-convex lens, appr. 200 m wide, more than 45 m thick. Their age was deduced biostratigraphically from ostracods. According to the petrographical treatment, a part of the Middle Pleistocene deposits belongs into poorly graded gravelly sands of litharenite composition, without limestone pebbles. Beside the predominant sandstone pebbles there also appear, in a significant portion, quartzite, polycrystalline quartz, extrusive rocks and/or tuff pebbles.

Overlying the Upper Pontian and, locally, Middle Pleistocene deposits, across the whole of the study area, are gravels and sandy gravels containing up to 70% of pebbles. Their thickness mostly varies between 7.6 and 9.4 m. On the basis of superposition, substratum characteristics, petrographic composition and the climate in Quaternary it has been concluded that they are of Holocene age.

The reconstruction of the genesis of Middle Pleistocene and Holocene sediments begins with the hiatus from the Upper Pontian. In this period the weathered layer and palaeorelief were formed in the following manner. The local vertical neotectonic uplifting of a lesser Neogene horst increased erosion caused the origin of furrow-like depressions, trending approximately north-east to south-west and with an inclination in the north-east direction. In the Middle Pleistocene such local depressions became swamps and/or lakes due to the nearness of the increased humidity pluvial belt. They probably existed from the Mindel/Riss interglacial into lower Riss, until glaciation conditions became too extreme. Swift currents, particularly strong in rainy seasons, suddenly lost their energy flowing into such a swamp/lake. Poorly graded and resedimented detritus was deposited in the immediate vicinity of the bank. The petrographic composition of these sediments points to Medvednica, Marijagorička brda and Žumberačko

gorje as the source area.

Due to progressive cooling and draught during Riss, shallow sweet water surfaces dried up (with a possible exception of larger and deeper lakes). The depositional hiatus lasted during the Upper Pleistocene, the Würm being the coolest and driest period of Quaternary glaciations altogether.

The beginning of the Holocene, was characterised by a sudden warming up, and initiation of a cycle of sedimentation. Melting of the Alpine regions' glaciers occurred at that time which, together with some tectonic uplift, enabled a breakthrough of the torrential river and genesis of layers with essentially different facies characteristics. These are medium-grained to coarse-grained gravels with well rounded pebbles of predominantly limestone composition. In comparison with the Middle Pleistocene gravels, they are the product of a different sedimentation mechanism and an another source region - mostly the Alps.

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POTPOVRŠINSKA RASPROSTRANJENOST I FACIJESNE ZNAČAJKE TALOŽINA U PODRUČJU IZMEĐU ZAPREŠIĆA I SAMOBORA

J. Velić i B. Saftić

1. UVOD I PREGLED REZULTATA DOSADAŠNJIH ISTRAŽIVANJA

Godine 1988. obavljena su kompleksna istraživanja lokacije HE Podsused sa ciljem konačne procjene podobnosti predložene pozicije. Tom su prigodom prikupljeni i obrađeni raznovrsni podaci o neogenskim i kvartarnim taložinama. U ovom radu iznose se nove spoznaje u odnosu na potpovršinsku rasprostranjenost, litološke odlike, stratigrafsku pripadnost i uvjete geneze srednjopleistocenskih naslaga. Pri tome su u velikoj mjeri korištene metode iz domene dubinskog kartiranja što je rezultiralo konstrukcijom više grafičkih prikaza - karata i korelacijskih profila od čega su u članku kao ilustracije upotrebljeni samo profili.

Istraživano područje se nalazi uz Savu, na njezinoj lijevoj obali, 1100 m zapadno od utoka Krapine (Sl. 1a). Kote terena variraju od 123 do 125,5 m. Na njemu se osim oranica i livada prostiru i, zbog bujne vegetacije, neprohodni predjeli. U kišnim sezonama nastaju močvarišta i blatišta. U blizoj okolici nema izdanaka starijih kvartarnih sedimenata te su neposredne informacije o njima ovisne isključivo o bušenju.

Kvartarološki radovi područja između Zaprešića i Samobora oskudni su i malobrojni. Stanovite spoznaje o pleistocenskim taložinama stare su gotovo stotinu godina, a zatim nakon prekida od 60 godina uslijedilo je nešto više radova. Jedan od prvih autora GORJANOVIĆ-KRAMBERGER (1908) razlučio je tvorevine diluvija u dvije skupne: pristranačne ilovine i dolinski diluvij pretežno žute i sive boje, koji djelomice predstavlja taložine nekadašnje močvare, jezeru nalične. Močvara je prekrivala savsku ravnicu vukući podrijetlo još iz gornjega pliocena. D. BORČIĆ et al. (1968) su ustanovili da ispod vodonosnih šljunaka i pijesaka leži prvo smeđa, šljunkovita glina i zatim masna, sivoplava slična pleistocenskim i mlađim pliocenskim naslagama.

Morfometrijskom analizom koju je sproveo PRELOGOVIĆ (1969; 1970), osobito uz pomoć karte izolonga II reda rekonstruiran je reljef oblikovan nakon odlaganja plioleistocenskih sedimenata vrlo nalik recentnom. Studirajući mineraloško-petrografski sastav nanosa rijeke Save CRNKOVIĆ & BUŠIĆ (1970) su zapazili da se idući od Krškoga polja, preko Zaprešića i Rakitja do Jaruna i Novoga Čiča valutice mijenjaju od izrazito dolomitno-vapnenačkih do karbonatnih sa

znatnim udjelom kvarca i kvarcnih klastita.

Najcjelovitiji prikaz o kvartarnim sedimentima u dolini Save kraj Samobora potječe od KOVAČEVIĆA i CAPARA (1972). U zaključku između ostaloga navode da je područje sjeverno od Nedjelje prema Savi zapunjeno zamašnim naslagama nanosa pri čemu je šljunčano-pješčani sloj debljine do 15 m samo njihov plići dio. Glinovite naslage sa šljunkom sežu lokalno i dublje od 45 m, za razliku od mjesta gdje se lapor nalazi odmah na 10 do 15 m od površine. Slično su konstatareli ŠIKIĆ & BASCH (1975) te ŠIKIĆ et al. (1979). Oni, naime, također iznose da je prosječna debljina aluvijalnog šljunčano-pješčanog sloja u Krškom i Brežičko-samoborskom polju oko 10 do 12 m, mjestimice i veća, uz dopunu da njihovu podlogu tvore miocenski i pliocenski sedimenti.

Detaljnija kronostratigrafska podjela kvartarnih taložina, između ostaloga i zapadno od Podsuseda, sadržana je u radu ČAKARUN et al. (1987). Izdiferencirani su gornjopleistocensko-holocenski, srednjopleistocenski i gornjopliocenski-donjopleistocenski klastiti različitih granulometrijskih značajki. VELIĆ (1989) u osnovnim je crtama opisala karakteristike potpovršinskih srednjopleistocenskih sedimentnih tijela u dolini Save od Bregane do Podsuseda.

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2. O ISTRAŽIVAČKIM RADOVIMA

Sadržaj i obujam istraživačkih radova planirani su tako da pruže što više pouzdanih i raznovrsnih geološko-geomehaničkih podataka. U tom su smislu sprovedena geofizička mjerenja (uključujući i ona u bušotinama), bušenje, determinacija jezgara te laboratorijske i kabinetske analize uzoraka. Korelacijom i interpretacijom svih podataka postignute su daljnje, nove spoznaje o razvoju kvartarnih klastita.

Od geofizičkih metoda obavljeno je geoelektrično

sondiranje-profiliranje i plitka refrakcija. U bušotinama je izmjerena prirodna i izazvana radioaktivnost, tj. snimljene su γ krivulje (Sl. 2, krivulje lijevo i desno od litoloških stupova. Na uspješnije snimljenim karotažnim dijagramima gustoće (što je sinonim mjerenja inducirane radioaktivnosti) vidi se da oni dobro odražavaju i zbijenost naslaga.

Na površini od oko 7,5 ha izrađeno je 18 bušotina doseg kojih se kretao od 15 do 60,2 m (Sl. 1 a). Iz svih je izvađena jezgra pomoću široke jednostruke sržne cijevi. Kontinuirano s bušenjem determinirana je jezgra i prikupljeni su uzorci:

- šljunka i šljunkovitog krupnozrnastog pijeska za petrografske analize,
- pijeska zbog određivanja mineralnog sastava pomoću polarizacijskog mikroskopa,
- prašinsto-glinovitih intervala za rentgenska snimanja,
- prašinsto-pjeskovitih taložina za mikropaleontološku obradu te
- različitih tipova sedimenata za granulometrijske analize.

3. LITOLOGIJA I STRATIGRAFIJA

Od najveće su važnosti bile najdublje bušotine- B-3, B-11 i B-12 - kojima su obuhvaćene pontske, pleistocenske i holocenske taložine doprijevši do dubina od 54,5 odnosno 60,2 m.

Sedimenti gornjeg a p o n t a zahvaćeni su svim bušotinama - osim u B-3 - u debljinama od 4,4 do 42,7 m. Zastupljeni su decimetarskim ili centimetarskim izmjenama glinovitog silta i sitnozrnastog, rjeđe srednjozrnastog, pijeska sive, sivosmeđe i sivoplavkaste boje. Rijetki su deblji slojevi izgrađeni od samo jedne granulometrijske frakcije. Prigodom determinacije u njima su mjestimice uočeni krhki, izlomljeni fosilni školjkaši. Krivulje prirodne radioaktivnosti i granulometrijskog sastava (Sl. 2 i 3) ukazuju na tendenciju postupnog povećanja udjela gline s dubinom, većinom od 30. m ispod površine terena.

Svi uzorci pijeska, praha i gline prikupljeni da bi se odredio mineralni sastav, pripadaju upravo ovom kronostratigrafskom nivou (Sl. 1c). U njemu je dominantan kvarc, a kao glavne komponente slijede plagioklasi, tinjci (muskovit/sericit), karbonati (uz evidentnu prevagu dolomita) i klorit. U teškoj su frakciji kvalitativno utvrđeni epidot, coisit, granat, amfibol, titanit, disten, apatit, cirkon i opaki minerali. Identične spoznaje da je kvarc glavni u lakoju, a epidot u teškoj mineralnoj frakciji pijesaka objavili su ŠIKIĆ et al. (1979) te ŠIMUNIĆ & ŠIMUNIĆ (1987).

Gornjopontska starost ovih sitnozrnastih klastita pouzdano je dokumentirana mnogobrojnom faunom ostrakoda karakterističnom za kaspibrakičnu sredinu. Određene su slijedeće vrste (odredila A. SOKAČ): *Hungarocypris* cf. *annonica* (ZALANYI), *Amplocypris reticulata* (ZALANYI), *Candona* (*Caspiocypris*) *labiata* (ZALANYI), *C. (Caspiocypris) alta* (ZALANYI), *C. (Caspiocypris) sp.*, *C. (Camptocypris) balcanica*

(ZALANYI), *C. (Camptocypris) cf. hungarica* (ZALANYI), *C. (Camptocypris) sp.*, *C. (Lineocypris) branka* KOSTIĆ, *C. (Lineocypris) trapezoidea* SOKAČ, *C. (Lineocypris) sp.*, *C. (Pontoniella) sp.*, *Bacunella dorsoaricata* (ZALANYI), *Leptocythere sp.*, *Hemicytheria pejinovicensis* (ZALANYI), *Hemicytheria sp.* SOKAČ, *Cyprideis triangulata* KRSTIĆ i *C. seminulum* (REUSS).

Na kraju opisa ovoga člana naročito je značajno istaknuti karakteristike njegovog najmlađeg, vršnog dijela. To je redovito 20 do 50 cm debeli sitnozrnasti prašinsti pijesak markantnog "šarenog" izgleda zbog nepravilnog mrljastog obojenja u žučkastosmeđastim nijansama. Jedino uzorak toga intervala sadrži uz ostale spomenute minerale, vrlo slabo kristalizirani getit i amorfnu željeznu hidroksid. Njihov nalaz upućuje na postojanje kore trošenja jer im je geneza vezana za oksidaciju minerala koji u sebi imaju željezo.

Gornjopontske taložine registrirane su većinom približno 10 m od površine. Međutim, izradom bušotine B-3 signalizirana je pojava koja odstupa od dotadašnjeg redanja litoloških, a time i kronostratigrafskih članova. Umjesto sitnozrnastih sivih sedimenata, jezgrenom cijevi su na površinu iznijeti s r e d n j o p l e i s t o c e n s k i šljunci, pijesci, prahovi i gline i to u intervalu od 9,0 do 54,5 m, dakle do dna bušotine. Prvenstveno na osnovi determinacije jezgre te prema granulometriji (Sl. 2 i 3) moguće je u njima izdvojiti osam nivoa. Idući odozgo prema dolje to su:

- smeđasti šljunak i pijesak, slabo cementirani, debljine 6,3 m,
- masna, siva i sivosmeđa glina s utisnutim valuticama raznih veličina, debljine 2,7 m,
- nesortirana mješavina šljunka, pijeska i praha, mjestimice slabo vezana, debljine 10,6 m,
- glina prašinsto tamnosive boje s vrlo rijetkim valuticama i tankim proslojcima pijeska, debljine 0,6 m,
- izmjena sitnozrnastog pijeska, praha i gline u nijansama sive boje, sa sporadičnim valuticama i krhkim fosilnim školjkašima, debljine 12,2 m,
- svijetlosivi šljunak i sitnozrnasti do srednjozrnasti pijesak uz nešto praha debljine 7,1 m,
- sivozelenkasti glinoviti prah s pojavom šljunka bliže podini, debljine 3,9 m,
- žučkastosmeđa prašinsto glina debljine 2,1 m.

Zbog načina uzimanja granulometrijskih proba, u prikazu za B-3 na Sl. 3 nisu u potpunosti došle do izražaja opisane promjene.

Prema petrografskoj obradi uzorka vršnog dijela srednjopleistocenskih naslaga, one spadaju u loše sortirane šljunkovite krupnozrnaste pijeske pješčenjačkog sastava. Među valuticama uopće nema vapnenačkih (Sl. 1b). Dominiraju valutice pješčenjaka s udjelom od 47,5% te valutice kvarcita i polikristalnog kvarca s 28,8%. Uz njih se još nalaze samo valutice efuziva i/ili tufova (10,2%), kristalastih škrljavaca (8,5%) i dolomita (5%). Slično je utvrdila R. MUTIĆ (ČAKARUN et al., 1987).

Na srednjopleistocensku starost ukazali su rezultati

mikropaleontološke obrade uzorka pjeskovito-glinovitog praha tamnosmeđe boje iz bušotine B-12 uzetog s dubina od 18,0 do 18,2 m. Uz mikromoluska, girogonije hara i ostatke inkrustiranog korijenja (*Rhizosolenia*) određene su slijedeće vrste ostrakoda: *Candona neglecta* SARS, *C. compressa* (KOCH) BRADY, *Cyclocypris ovum* (JURINE), *C. laevis* (O. F. MÜLLER) i *Scottia tumida* (JONES). Od navedenih, ovdje je s kronostratigrafskog aspekta svakako najznačajnija *Scottia tumida* (JONES) koja je brojna i učestala vrsta u srednjem pleistocenu naših krajeva (SOKAČ, 1978).

Rasprostranjenost ovih sedimenata vrlo je ograničena što je zorno predočeno profilima A-A' i B-B' (Sl. 2 i 3). Osim u bušotini B-3 koja nije doprla do podine, utvrđeni su još samo u B-11 i B-12 u intervalima od 13,5 do 29,2 m, odnosno 9,6 do 22,4 m. Tijelo koje se očitava slično je plankonveksnoj leći širine oko 200 m i debljine veće od 45 m.

Povrh naslaga gornjega ponta, odnosno srednjega pleistocena na cijelom istraživanom području rasprostiru se 6,6 do 13,1 m (najčešće 7,6 do 9,4 m) debeli šljunci i pjeskoviti šljunci (Sl. 2 i 3). Petrografskom obradom utvrđeno je da pripadaju šljuncima vapnenačkog sastava, a pojavljuju se s nešto pijesaka i praha blijedožučkaste do svijetlosive boje. Odozdo prema gore veličina valutica opada pa su u tom smislu odvojena dva intervala (Sl. 2 i 3):

- donji, stariji s krupnijim valuticama šljunka i
- gornji, mlađi sa sitnijim valuticama šljunka uz pijesak i prah.

Oba intervala su gotovo podjednake debljine s lokalnim zadebljanjima ili istanjenjima jednog ili drugog intervala.

Ovisno o granulometrijskom sastavu šljunci sadrže između 57,8 i 70,1% valutica vapnenca, 7,8 do 13,4% dolomita i 8,9 do 16,4% pješčenjaka (Sl. 1b). Ostali petrografski tipovi kao na primjer kvarcit, rožnac, konglomerati, kiseli intruzivi, efuzivi i tuf sudjeluju u sastavu s udjelima od po samo nekoliko postotaka i redovito pripadaju najsitnijoj frakciji - 4,15 mm.

Fosilnih nalaza nije bilo što također spominju ŠIKIĆ et al. (1979). Spomenuti autori su krupnozrnaste šljunke i pijeske u kojima se najčešće pojavljuju dobro zaobljene valutice karbonata uvrstili u pleistocensko-holocenski aluvijalni nanos. ČAKARUN et al. (1987) nešto su određeniji svrstavši pripovršinske 7 do 12 m debele vrlo krupnozrnaste šljunke i pijeske u gornji pleistocen-holocen.

Na osnovi superpozicije, značajki podine, petrografskog sastava, klime u kvartaru i mehanizma taloženja nameće se zaključak da su ovdje opisani vapnenački šljunci holocenske starosti.

Cijeli teren prekriven je prašinsto-pjeskovitim, organskim tvarima bogatim materijalom svijetlosmeđe boje - humusom. Njegova debljina se kreće u rasponu od 0,3 do 0,8 m.

4. GENEZA SREDNJOPLEISTOCENSKIH TALOŽINA

Na osnovi rezultata terenskih, laboratorijskih i kabinetskih istraživanja moguće je rekonstruirati proces postanka ili litogenezu srednjopleistocenskih i holocenskih taložina. U tom se smislu u nastavku razmatra koje su stijene predstavljale izvor detritusa, kako je on bio transportiran na mjesto sedimentacije, kakvi su bili facijesi i sredine taloženja, tj. mehanički, fizičko-kemijski i biološki uvjeti te kakvog su oblika i veličine tijela ovih kvartarnih tvorevina.

Podlogu ili paleoreljef na kojega diskordantno naliježu kvartarne naslage izgrađuju gornjopontski pjeskoviti prahovi. Tijekom hijatusa do srednjega pleistocena na njihovoj je površini formirana kora trošenja u debljini od 20 do 50 cm žučkastosmeđe boje. Tome u prilog govori prisutnost slabo kristaliziranog getita što je uz naznačenu boju posljedica oksidacije u aerobnim uvjetima (FITZPATRICK, 1971). Istovremeno je postupno nastajao relativno razvedeni paleoreljef. Njegov izgled u izravnoj je svezi s vertikalnim neotektonskim kretanjima. Nairne, obrađeni teren leži na neogenskom horstu omeđenom rasjedima koji se pružaju po pravcu sjeverozapad-jugoistok na udaljenosti jedan od drugoga od oko 1000 m (PRELOGOVIĆ, 1969; 1970). Uklopljen je u konturu oznake za lokalno neotektonsko izdizanje. Uz litološki sastav, upravo je izdizanje izazvalo povećanu eroziju zahvaljujući kojoj su nastala žljebasta udubljenja orijentirana približno sjeveroistok-jugozapad s nagibom u smjeru sjeveroistoka. Takva su udubljenja omogućila sedimentaciju srednjopleistocenskih šljunaka, pijesaka i praha i njihovu "poštedu" od erozije i denudacije u hijatusu koji je trajao do početka odlaganja aluvijalnih šljunaka vapnenačkog sastava, do početka holocena.

U srednjem pleistocenu, vjerojatno u njegovu starijem dijelu - mindel/riss interglacijalu - prvenstveno kao posljedica blizine pluvijalnog pojasa povećane humidnosti (MARKOV, 1970) formirane su vode stajačice, močvare ili jezera manjih dimenzija ispunjavajući udubljenja u paleoreljefu. Vodene površine egzistirale su i tijekom starijeg rissa, sve dok glacijalni uvjeti nisu postali ekstremni. Zbog boljeg razumijevanja ovdje treba obrazložiti na kakve se klimatske elemente misli.

Kao prvo, temperaturne krivulje glacijalnih razdoblja nisu simetrične, već asimetrične (ŠEGOTA, 1966; 1967). Minimalne temperature nisu vladale sredinom glacijala već bliže njihovog kraja. Relacija trajanja postupnog zahlađenja do maksimuma i naglog zatopljenja iznosi 4:1. Ova relacija je za sve glacijale jednaka. Ako se sadašnja srednja godišnja temperatura centralne Europe uzme da je 8°C onda je u doba mindel/riss interglacijala ona bila viša za 1 do 3°C, a u vrijeme maksimalnog riss glacijala čak 11°C niža. Drugim riječima, za vrijeme starijeg srednjega pleistocena srednja godišnja temperatura procijenjena je na 9 do 11°C, da bi pri njegovu kraju pala na -3 do -2°C (PESCI 1963; ŠEGOTA, 1967). Osim

temperature, za genezu kvartarnih taložina važna je još jedna klimatska značajka. To je vlažnost. Prema MARKO VU (1970) Zagreb i okolica ležali su za vrijeme pleistocena u periglacialnoj zoni gdje je progresivno zahlađen je bilo praćeno sve izrazitijom sušom.

Opisana klima odrazila se i na fosilni sadržaj. U tom je smislu značajan nalaz u zajednici ostrakoda *Candona neglecta* koja se ubraja u stenotermalne hladne vrste karakterizirajući još i oligohalinu sredinu (SOKAČ, 1976; 1978). Paleoeološki uvjeti ocrtavaju se jasnije ako se u obzir uzmu još i učestali ostaci oogonija hara i inkrustirani korjenčići sitnih biljaka čiji je naziv "Rhizosolenia" uveo HILTERMANN (1952). Zaključak je da se ovdje radi o plitkoj slatkovodnoj sredini, siromašnoj otopljenim solima, koja je periodično presušivala. Na pjeskovitom i muljevitom dnu uz ostrakode obitavale su i sitnije biljne vrste. Oligohalino obilježje može biti indikacija da su opisane močvare ili jezera prihranjivane pretežno oborinskim vodama.

Dalja stanovita potvrda o sedimentaciji dijela razmatranih naslaga za vrijeme hladnijeg, mlađeg srednjeg pleistocena može se naći i u činjenici da su "Rhizosolenia" tvorevine izgrađene od zrnaca pijeska slijepljenih kalcijevim karbonatom čija geneza jako podsjeća na postanak sedre. Biljka, uzimajući CO₂ iz otopljenog kalcijum-bikarbonata izaziva obaranje kalcita. S obzirom da topivost kalcita raste s opadanjem temperature (KRAUSKOPF, 1985) brojnost nalaza inkrustacija može se eventualno povezati i s količinom otopljenog kalcijum-bikarbonata baš zbog toga razloga.

Granulometrijski sastav, prema kojemu su se istovremeno taložili šljunci, pijesci, prah i gline (Sl. 3) posljedica je odlaganja u uvjetima brze sedimentacije u vodenoj sredini nakon naglog pada energije voda. U kišnim razdobljima bujice koje su transportirale detritus, slijevajući se u močvaru/jezero naglo su gubile energiju pri čemu se u neposrednoj blizini obale sedimentirao loše sortirani, nekoliko puta pretaloživani materijal. S obzirom na petrografske sastav, područje distribucije je bilo pretežno izgrađeno iz donjotrijaskih i paleozojskih klastita koji se rasprostiru po okolnim uzvišenjima - Medvednici, Marijagoričkim brdima i Žumberačkom gorju.

Kontakt gornjopontskih i srednjopleistocenskih naslaga danas nije obilježen, između ostaloga, smeđom korom trošenja. Prevlake željeznog oksihidroksida koje daju sedimentima žutosmeđu boju otopljene su pod utjecajem voda stajačica, praćeno zahlađenjem. Proces se odvijao na slijedeći način: postupnim smanjenjem kisika u pridnenoj zoni aktiviraju se fermentacijski procesi iz kojih nastale kiseline reduciraju željezne specije. To su procesi slični suvremenim uvjetima pod kojima nastaju tzv. "glej" sedimenti u jezerskim i močvarnim muljevima na područjima kontinentalnih tajgi i stepa (PLEREL'MAN, 1967; 1975).

Postupnim napredovanjem zahlađenja u rissu prema maksimumu od -3°C prosječne godišnje temperature i ovaj dio glacio-periglacialnog pojasa postaje izrazito

suh. U plitke slatkovodne sredine pristiže sve manje vode, lokalno do konačnog presušivanja. Odgovor na pitanje da li je za vrijeme od 40 000 godina interglacijala riss/würm sedimentacija obnovljena treba tražiti tamo gdje su pleistocenski sedimenti deblji u odnosu na ovdje opisane. Naime, neke bušotine izrađene sjeverno od Samobora i Nedjelje na desnoj obali Save, duboke više od 100 m nisu doprle do podloge kvartara. Vjerojatno je da su takve debljine posljedica sedimentacije bilo kontinuirane bilo obnovljane tijekom mindel/riss i riss/würm interglacijala te riss glacijala u nešto dubljim i prostranijim jezerima ili jezeru koje treba povezati sa zonama karakteriziranim postojanim neotektonskim spuštanjem.

Würmski glacijal je bio najhladnije razdoblje kvartarnih oledbi s -4°C prosječne godišnje temperature tijekom njegove zadnje četvrtine (ŠEGOTA, 1966; 1967) praćeno još izrazitijom suhoćom (MARKOV, 1970). Ovakva klimatska obilježja pogodovala su kontinuitetu prekida sedimentacije sve do početka holocena, kada dolazi do naglog zatopljenja uz temperature kakve vladaju danas.

Otapanjem ledenjaka alpskih predjela uz određene tektonske procese stvoreni su uvjeti za nastavak taloženja, ali ovaj puta s bitno drugčijim facijesnim značajkama. Zahvaljujući proboju rijeke (Sava) bujičnog karaktera transportiraju se i odlažu srednjozrnasti do krupnozrnasti šljunci s dobro zaobljenim valuticama promjera između 4 i 45 mm kod kojih izrazito dominira vapnenački sastav. Najčešće su valutice vapnenaca koji bi stratografski odgovarali trijaskim, jurskim, a rjeđe i krednim karbonatima. Na njima su zamijećeni tragovi intenzivnih kataklaziranja, tektonska drobljenja i pucanja, a nerijetko i dijagenetske promjene kao što su rekristalizacija i silifikacija. Dolomitne valutice sa sigurnošću se može smatrati da potječu iz gornjotrijaskog "hauptdolomita". U usporedbi sa srednjopleistocenskim naslagama, ove pripadaju drugom mehanizmu taloženja i drugom izvorišnom području detritusa za kojeg se uglavnom mogu smatrati Alpe.

Svuda gdje ovi najmlađi šljunci naliježu izravno na pontske naslage ustanovljena je smeđasta kora trošenja ukazujući da oksihidroksidi željeza nisu reducirani. Iznad njih tekle su dinamične vode s dovoljno kisika održavajući i dalje oksidacijske uvjete.

5. PREGLED POSTIGNUTIH REZULTATA

Na lijevoj obali Save, 1100 m zapadno od utoka Krapine, na površini od oko 7,5 ha sprovedena su cjelovita geološko-geomehanička istraživanja uz primjenu geofizičkih mjerenja i bušenja sa 100% jezgrovanjem. Prikupljeni su uzorci jezgara za petrografske, mineraloške i granulometrijske analize te za mikropaleontološku obradu.

Tri bušotine duboke 54,5 do 60,2 m zahvatile su idući odozdo prema gore pontske, pleistocenske i holocenske naslage. U 15 preostalih bušotina utvrđene

su samo pontske i holocenske taložine (Sl. 2 i 3). Sedimenti gornjeg pontsa zastupljeni sivosmeđastim i sivoplavim, tankim slojevima i laminama glinovitog silta i sitnozrnastog pijeska sadržavali su bogatu faunu ostrakoda dostatnu za kronostratigrafsku odredbu. U vršnom dijelu ovih stijena žučkastosmeđe boje debljine 20 do 50 cm utvrđen je između ostalih minerala i getit što upućuje na procese trošenja minerala sa željezom u svom sastavu.

Srednjopleistocenske šljunke, pijeske, prahove i gline debljine veće od 45 m moguće je razlučiti u osam karakterističnih nivoa. To su izmjene krupnih i sitnijih klastita sivih i smeđih boja u debljinama od 2,7 do 12,2 m. Njihova je rasprostranjenost vrlo ograničena (profili A-A' i B-B' na Sl. 2 i 3). Tvore tijelo koje je moguće usporediti s plankonveksnom lećom širine oko 200 m i već spomenute debljine veće od 45 m. O njihovoj starosti zaključeno je na osnovi nalaza zajednice ostrakoda. Prema petrografskoj obradi, dio srednjopleistocenskih taložina spada u loše sortirane šljunkovite pijeske litoarenitskog sastava bez vapnenačkih valutica. Uz dominantne valutice pješčenjaka dolaze još sa značajnim udjelom i valutice kvarcita, polikristalnog kvarca, efuziva i/ili tufova.

Iznad taložina gornjeg pontsa i lokalno, srednjeg pleistocena, na cijelom obrađenom području leže šljunci i pjeskoviti šljunci s do 70% vapnenačkih valutica. Njihova debljina se najčešće kreće u rasponu od 7,6 do 9,4 m. Na osnovi superpozicije, osobina podine, petrografskog sastava i klime u kvartaru zaključeno je da su holocenske starosti.

Rekonstrukcija geneze srednjopleistocenskih i holocenskih sedimenata započinje hijatusom od gornjega pontsa tijekom kojega je formirana kora trošenja i

palcoreljeft na slijedeći način. Lokalno vertikalno neotektonsko izdizanje jednog manjeg neogenskog horsta i sukladno tome pojačana erozija rezultirali su nastankom žljebastih udubljenja orijentiranih približno po pravcu sjeveroistok-jugozapad s nagibom u smjeru sjeveroistoka. U srednjem pleistocenu zbog blizine pluvijalnog pojasa pojačane humidnosti takve lokalne depresije postaju močvare i/ili jezera. Njihovo trajanje se vjerojatno protezalo iz mindel/riss interglacijala i u stariji riss sve dok glacijalni uvjeti nisu postali ekstremni.

Slijevajući se u takvu močvaru / jezero bujični tokovi naročito intenzivni u kišnim sezonama, naglo su gubili energiju. Pri tome se neposredno uz obalu taložio loše sortirani, više puta pretaložavani detritus. Njegov petrografski sastav upućuje na Medvednicu, Marijagorička brda i Žumberačko gorje kao izvorišno područje.

Zbog progresivnog zahlađenja i suše u rissu plitke slatkovodne površine presušuju (osim možda veća i dublja jezera okolice ovdje tretiranog terena). Hijatus traje i tijekom gornjeg pleistocena jer je upravo würmski glacijal najhladniji i najsuši period kvartarnih oledbi uopće.

S početkom holocena karakterističnog po naglom zatopljenju započinje novi ciklus sedimentacije. Tada dolazi do otapanja ledenjaka alpskih predjela što zajedno sa stanovitim tektonskim procesima omogućava proboj bujične rijeke i genezu naslaga s bitno drugačijim facijesnim osobitostima. Radi se o srednjozrnastim šljuncima dobro zaobljenih valutica dominantno vapnenačkog sastava. U usporedbi sa srednjopleistocenskim, ovi pripadaju drugačijem mehanizmu taloženja i drugom izvorišnom području - uglavnom Alpama.