GEOPHYSICAL TRANSACTIONS 1985
Vol. 31. No. 1-3. pp. 101-129

CONTRASTING TYPES OF NEARSHORE SANDS AND GRAVELS FROM SEMI-PROTECTED MIOCENE COASTS, NORTHERN HUNGARY

H. Edward CLIFTON*, Margit BOHN-HAVAS** and Pál MÜLLER**

Dissimilar types of nearshore clastic deposits occur in the Miocene sediment of northern Hungary. One of these is exposed in a small sand pit east of the village of Csokvaomány; it is part of the Salgótarján Formation of Ottnangian (early Miocene) age. The deposit is characterized by a 6.5-m-thick vertical sequence that appears to include inner shelf, nearshore, foreshore and backshore facies in upward-shallowing progression. The sequence is readily interpreted as the result of a shoreline prograding into an arm of the Miocene sea. The other deposit is exposed in a gravel pit east of the village of Nekézseny; it is part of the Egyházasgerge Formation of Karpathian (early or middle Miocene) age. This deposit consists of 21 m of calcareous and dolomitic sandy gravel deposited on a Paleozoic carbonate rock platform (or locally on a layer of fine siliciclastic sand just above this platform). The Paleozoic rock surface is intensively bored by *Lithophaga*. Fragments of bivalve shells, *Lithophaga*-bored pebbles, and large burrows in the gravel attest to deposition in a marine environment. The oscillatory velocities required to move the larger pebbles and paleogeographic constraints suggest deposition in water no more than several meters deep. Systematic vertical variation within the gravel is limited mostly to an upward fining of the siliciclastic component (fine sand near the base, silty very fine sand and clay near the top). The deposit is inferred to have occurred at the foot of a topographically high area (possibly an island) underlain by carbonate rock. Deposition of calcareous and dolomitic detritus was rapid enough to maintain a relatively constant water depth during the interval of sea level rise. The simultaneous retreat of an initially-adjacent siliciclastic shoreline to the north caused a fining of the siliciclastic component. Gravel deposition ceased upon inundation of the carbonate rock high, and accumulation of fine-grained sediment of the Garáb Formation completed Karpathian deposition.

Keywords: Miocene, marine shoreline deposits, progradation, molluscs, Northern Hungary

1. Introduction

The character of clastic shoreline deposits depends on the interplay of many factors, including the texture of available sediment, the physical dynamics of the environment, the biota, and the balance between sedimentation rate and relative change of sea level. This paper describes two different deposits that formed along Miocene shorelines in northern Hungary and analyzes their contrasting charasteristics in terms of causal factors.

During the lower and middle Miocene (Eggenburgian, Ottnangian, Karpathian and Badenian stages) narrow, shallow arms of the sea extended episodically across Hungary [Császár et al. 1982]. Gravel, sand, mud, volcanic ash and

* U. S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94 025
** Hungarian Geological Survey, POB 106, Budapest, H-1442
Manuscript received: 12 February, 1985

lignite accumulated in the shallow seaways or in the coastal swamps that locally bordered them. The distribution, stratigraphy, and lithologic character of these deposits have been established through the combined study of outcrops and boreholes developed through the Ottnangian brown coal research program of the Hungarian Geological Survey [SCHRÉTER 1929, 1945, and 1954, BALOGH 1964, RADÓCZ 1975, BOHN-HAVAS 1978].

Most of these deposits remain unconsolidated and are well-exposed only in artificial cuts. The exposures described here are in sand/gravel pits and are subject to change as the pits are expanded or abandoned.

2. Paleogeographic Setting

The deposits lie on the north flank of the Bükk Mountains; the pits in which they are exposed lie a short distance east of the villages of Csokvaomány and Nekézseny, respectively *(Fig. 1)*. They formed within the Egercsehi–Ózd Basin (the western part of the Borsod Basin). The boundaries of the basin are the

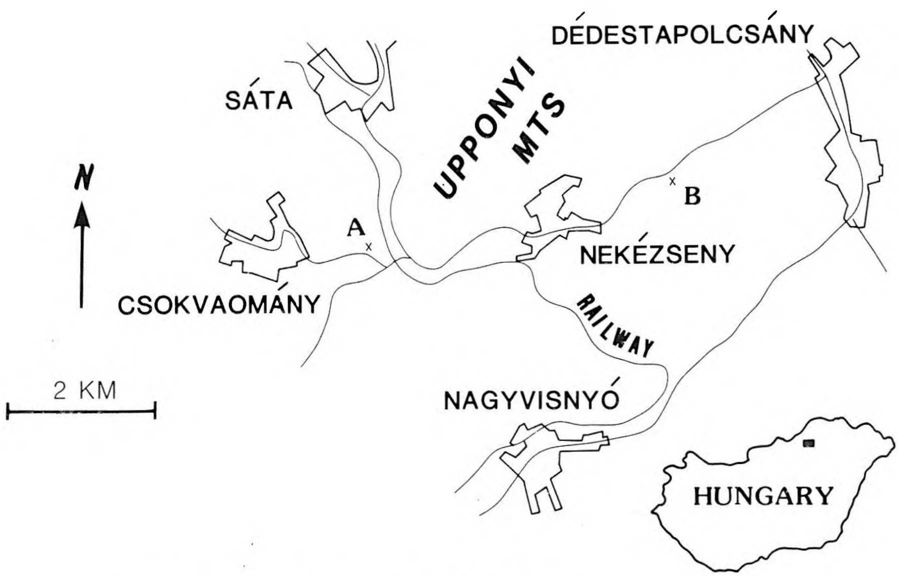


Fig. 1. Location of Miocene shoreline deposits described in this paper.
A — Ottnangian progradational sequence east of Csokvaomány; *B* — Karpathian calcareous gravel east of Nekézseny

1. ábra. A leírt miocén part menti üledékek helye.
A — ottnangi progradáló rétegsor Csokvaománytól keletre; *B* — kárpáti mészanyagú kavics Nekézsenytől keletre

Рис. 1. Размещение миоценовых прибрежных осадков, рассматриваемых в этой статье
А — Оттнангская проградационная толща восточнее с. Чокваомань; В — Известковистый галечник карпатского возраста восточнее с. Некежень

lower Paleozoic blocks of the Szendrő Mountains to the northeast, the Paleozoic–Mesozoic unit of the Bükk Mountains to the southeast, and the Pétervására Platform to the west. The northeast-southwest trending Egercsehi–Ózd trough apparently formed during the Savian orogenic phase (late Oligocene to early Miocene). The Miocene deposits in the trough are of Eggenburgian–Ottnangian (22–19 Ma) and Karpathian-lower Badenian (19-15 Ma) age [Hámor 1980, 1984].

The Eggenburgian and Ottnangian deposits represent two complete geologic cycles. During the Eggenburgian stage, the sea transgressed over northern Hungary from a north–northwest direction as a consequence of the Savian orogenic movements. Its transgression over the western part of the Borsod area filled the Egercsehi–Ózd Basin. A second Ottnangian sedimentary cycle *(Fig. 2)* more or less duplicated the earlier transgression [Hámor–Halmai 1975]. The Savian orogeny produced grabens that partly filled with rhyolitic tuffs erupted from marginal fractures (Gyulakeszi Rhyolite Tuff Formation, *Figure 3*).

Overlying the rhyolitic tuff in many places in the Egercsehi–Ózd Basin are sand, silt and clay of Ottnangian age: the Salgótarján Browncoal Formation (Fig. 3). This unit, which contains seams of lignite, formed during a slow transgression that was interrupted by minor oscillations of the sea. The faunal assemblages of the unit change progressively from brackish-water in the lower part to marine in the upper part. The lignites apparently formed under a humid climate in coastal swamps bordering the marginal sea.

During the Karpathian and Badenian stages another pair of sedimentary cycles ensued a different paleogeographic setting. As a result of the Styrian orogenic phase, a direct connection was established with the Mediterranean. Marine transgressions progressed from southwest to northeast through the Hungarian Basin to the Carpathians. The Karpathian transgression reached the area discussed here *(Fig. 4)* through the Budapest–Cserhát–Egercsehi–Ózd sedimentary trough [Hámor–Halmai 1975, Hámor 1983]. Littoral sand and gravel (Egyházasgerge Formation) and open marine marl and mud (Garáb Schlier Formation) accumulated during the Karpathian cycle (Fig. 2). Both units bear a marine macrofauna.

3. The Csokvaomány deposit

The older of the two deposits considered here is exposed in a small sand pit north of the highway about 1.5 km east of the village of Csokvaomány (Fig. 1). The width of the present wall of the pit is on the order of 10 m across, and about 10–12 m of section are exposed. Two depositional successions are present, separated by an erosional surface. The lower succession consists primarily of crossbedded and burrowed pebbly sand, in which a few oyster shells are scattered. The upper succession is mostly fine sand containing mud interbeds and numerous shell and shell fragments. The fauna *(Table I)* indicates that these deposits belong to the Ottnangian Salgótarján Browncoal Formation (Fig. 2).

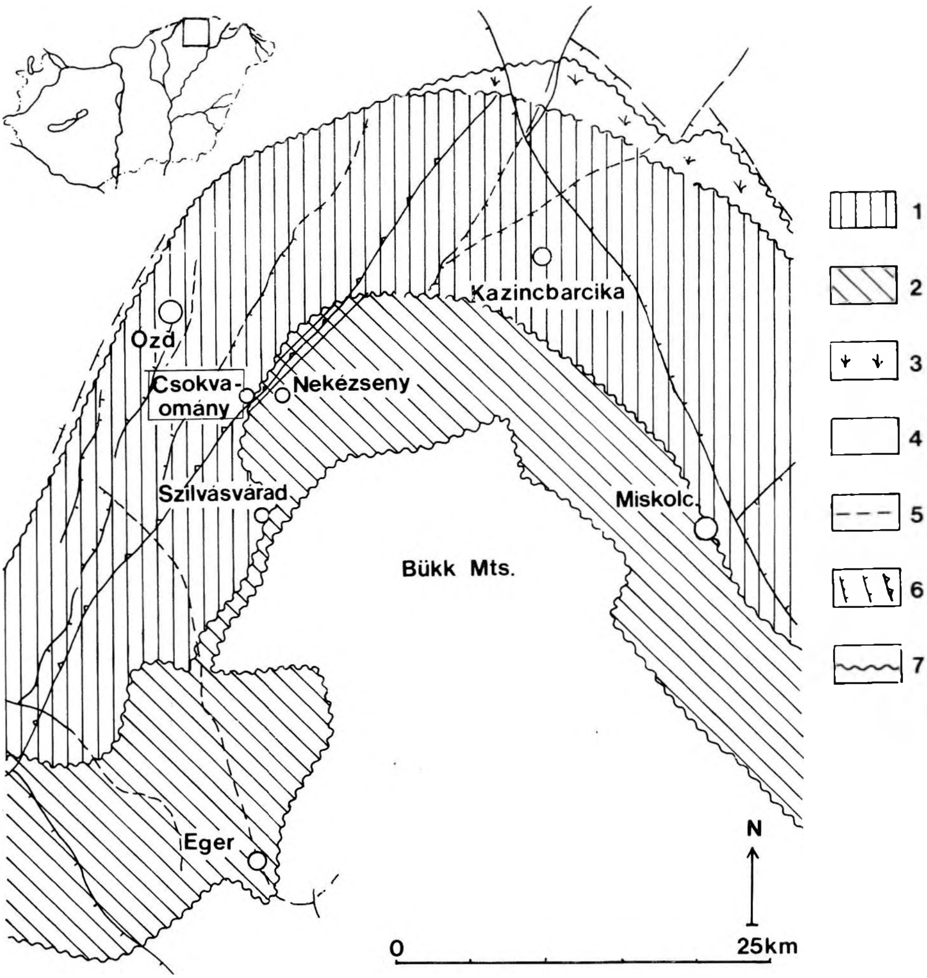


Fig. 2. Sketch map of paleogeography in northern Hungary during Ottnangian time
1 — paralic coal swamp; 2 — freshwater variegated clay; 3 — freshwater coal swamp; 4 — landmass; 5 — facies boundaries; 6 — structural elements; 7 — boundary of sedimentary basin

2. ábra. Északmagyarország ottnangi ősföldrajzának vázlata.
1 — paralikus kőszénmocsár; 2 — édesvízi tarkaagyag; 3 — édesvízi kőszénmocsár; 4 — szárazföld; 5 — fácies határ; 6 — szerkezeti elemek; 7 — az üledékes medence határa

Рис. 2. Картосхема палеогеографии территории Северной Венгрии в оттнангийское время
1 — болото образования паралических углей; 2 — пресноводные пестрые глины; 3 — пресноводное болото образования углей; 4 — суша; 5 — фациальная граница; 6 — структурные элементы; 7 — граница осадонного бассейна

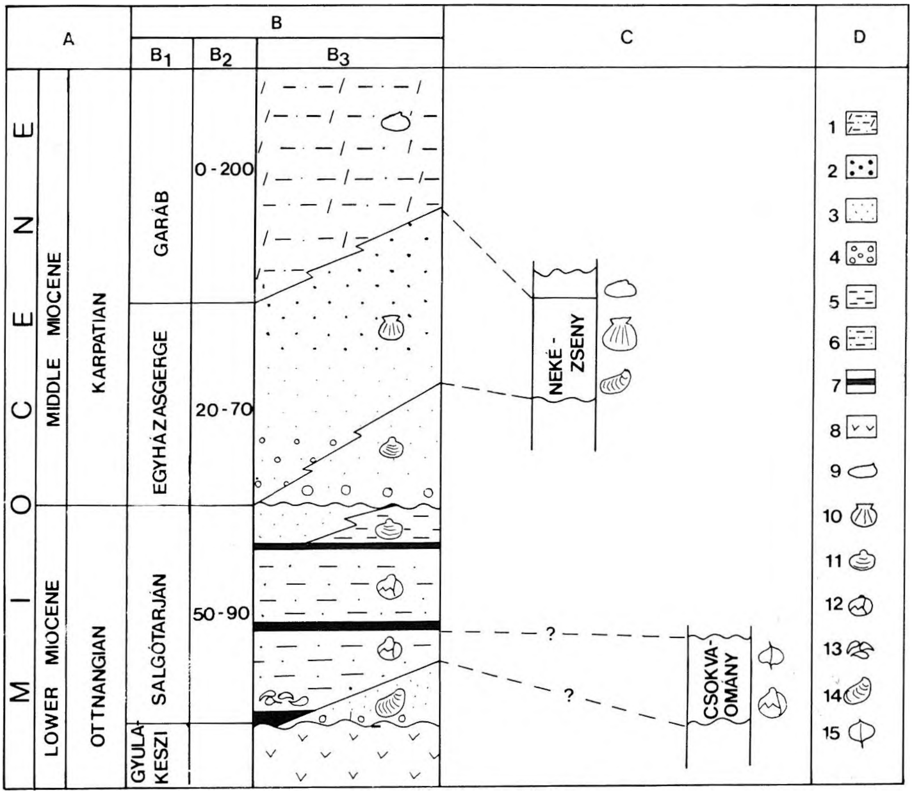


Fig. 3. Miocene (Ottnangian and Karpathian) units of the Egercsehi – Ózd Basin
A — Chronostratigraphy; B — Litostratigraphy; B_1 — Formation; B_2 — Average thickness; B_3 — Rock sequence; C — Location; D — Key to symbols.
1 — clayey silt; 2 — sandstone; 3 — sand; 4 — pebbles; 5 — clay; 6 — silt; 7 — browncoal seam; 8 — rhyolite tuff; 9 — *Macoma–Nucula* ass.; 10 — *Chlamys;* 11 — *Corbula–Anadara;* 12 – *Cardium–Pirenella–Theodoxus;* 13 — *Congeria;* 14 — *Crassostrea;* 15 — *Megatrola* fragments

3. ábra. Az egercsehi–ózdi medence miocén (ottnangi és kárpáti) egységei.
A — Kronosztratigráfia; B — Litosztatigráfia; B_1 — Formáció; B_2 — Átlagos vastagság; B_3- — Rétegsor; C — Lelőhely; D — Jelmagyarázat
1 — agyagos aleurit; 2 — homokkő; 3 — homok; 4 — kavics; 5 — agyag; 6 — aleurit; 7 — szén; 8 — riolttufa; 9 — *Macoma–Nucula* asszociáció; 10 — *Chlamys*; 11 — *Corbula–Anadara* asszociáció; 12 — *Cardium–Pirenella–Theodoxus* asszociáció; 13 — *Congeria*; 14 — *Crassostrea*; 15 — növénymaradvány

Рис. 3. Миоценовые (оттнангий и карпатий) единицы Эгерчехи–Оздского бассейна
А — Хроностратиграфия; В — Литостратиграфия; B_1 — Формация; B_2 — Средняя мощность; B_3 — Разрез; С — Месторождение; D — Условные обозначения
1 — глинистые алевриты; 2 — песчанник; 3 — пески; 4 — гальки; 5 — глины; 6 — алевриты; 7 — уголь; 8 — липаритовые туфы; 9 — ассоциация *Macoma–Anadara;* 10 — *Chlamys;* 11 — ассоциация *Corbula–Anadara;* 12 — ассоциация *Cardium–Pirenella–Theodoxus;* 13 — *Congeria;* 14 — *Crassostrea;* 15 — растительные остатки;

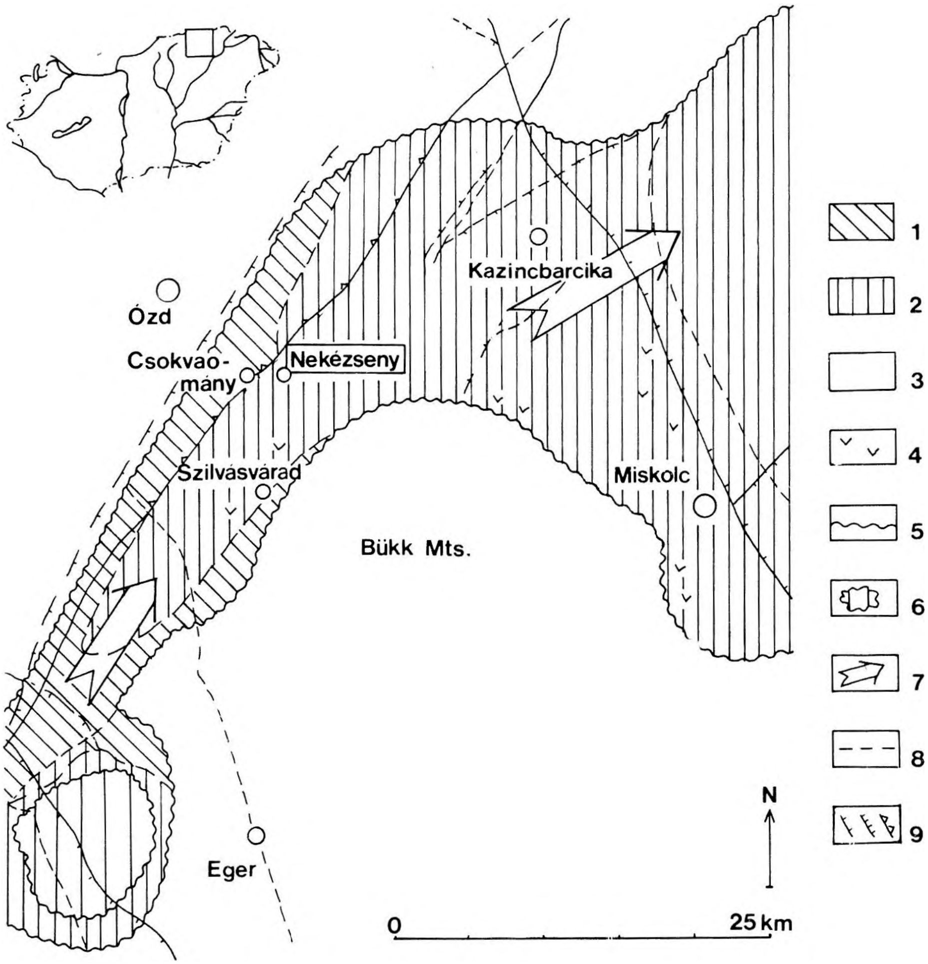


Fig. 4. Sketch map of paleogeography in northern Hungary during Karpathian time
Depositional facies: 1 — littoral, 2 — sublittoral, shallow open water. 3 — landmass; 4 — rhyolite tuff; 5 — coast-line during maximal transgression; 6 — sedimentary basin during regression; 7 — direction of transgression; 8 — facies boundaries; 9 — structural elements

4. ábra. Északmagyarország kárpáti ősföldrajzának vázlata.
Fácies: 1 — partszegélyi, 2 — sekély szublitorális tengeri. 3 — szárazföld; 4 — riolit tufa; 5 — partvonal maximális elöntés idején; 6 — üledékgyűjtő; 7 — transzgresszió iránya; 8 — fácieshatár; 9 — szerkezeti elemek

Рис. 4. Картосхема палеогеографии территории Северной Венгрии в карпатийское время
Фации: 1 — прибрежная, 2 — мелководного сублиторального моря, 3 — континентальная; 4 — риолитовые туфы; 5 — береговая линия во время максимального прилива; 6 — осадконакопители; 7 — направление трансгрессии; 8 — фациальная граница; 9 — структурые элементы

Table 1. Fossil assemblage in the Ottnangian deposit exposed east of Csokvaomány
1. táblázat. Ottnangi bentos faunaegyüttesek (Csokvaomány)
Таблица 1. Комплекс ископаемых остатков отложений оттнангийского яруса в обнажении к востоку от Чокваоманя

Fossils: Mollusca
- Bivalvia: *Musculus* sp.
  - *Congeria* sp.
  - *Ostrea* sp. (juv.)
  - *Cardium sociale* Krauss
  - *Cardium* sp.
  - *Pitaria* cf. *islandicoides* Lam.
- Gastropoda: *Theodoxus pictus* Fer.
  - *Hydrobia* sp.
  - *Pirenella* sp.

Annelida
- ?Polychaeta

Arthropoda
- Ostracoda

Megaflora fragments

The shoreline deposits described here occur in the underlying succession, which composes the lower 6.5 m of the exposure. This section displays a distinctive vertical sequence *(Fig. 5)*. The lowermost exposed strata consist of interlaminated mud and fine sand, the top of which is interrupted by layers of structureless coarse pebbly sand. The mud layers become progressively thinner, fewer and more discontinuous upward; they are absent in the section higher than about 2.5 m above the base. About 2 m above the base the sand and gravel change from predominantly structureless to mostly crossbedded. The section becomes progressively more pebbly up-section, culminating in a crossbedded gravel bed about 5 m above the base. Above this bed, the sediment become progressively finer and passes from planar-parallel laminated sand into structureless muddy sand that contains fossil root structures. This is capped by a thin (2–4 cm) lignite bed that is locally overlain by as much as 20 cm of mud that contains numerous gastropod shells. An erosional surface *(Fig. 6)* locally covered by a thin conglomerate (and scattered large clasts of silicified wood) terminates the lower succession.

The vertical sequence closely resembles those that form in response to a prograding shoreline [Harms et al. 1982]. In such a sequence, successively higher parts of the section represent progressively shallower parts of the nearshore environment. A key horizon in this sequence lies at the upward transition fromcrossbedded gravel to planar-bedded pebbly sand (the 0 m reference in Figure 5), which marks the presumed position of sea level. The lowermost strata in the sequence represent conditions of low energy under which mud and fine sand accumulated. Deposition in this quiet-water regime was interrupted episodically by the introduction of coarser sand in response to infrequent storms. If sea level is assumed to have remained more or less constant during the progradation, these conditions existed at depths as shallow as 4–5 m. The presence of pebbles greater than 1 cm in diameter in the storm deposits suggests

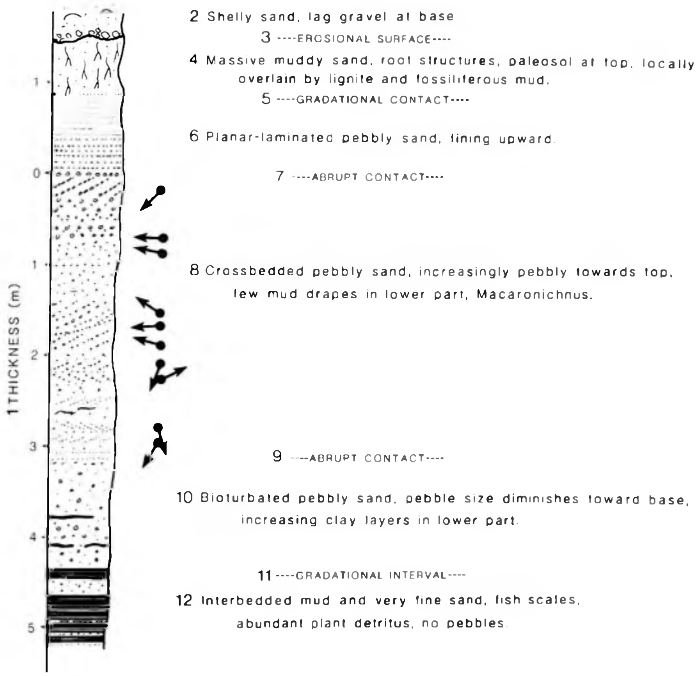


Fig. 5. Stratigraphic column of the lower sedimentary sequence exposed in the sand pit east of Csokvaomány. Arrows indicate crossbedding dip directions

5. ábra. A Csokvaománytól keletre lévő homokgödörben feltárt alsó üledékösszlet rétegoszlopa. A nyilak a keresztrétegződés dőlési irányait jelzik.
1 — vastagság; 2 — kagylóhéjas homok, maradékkavics a bázison; 3 — eróziós felszín; 4 — rétegzetlen iszapos homok, gyökérnyomok, őstalaj felül, részben lignittel és kövületes iszappal fedve; 5 — fokozatos átmenet; 6 — síkrétegzett kavicsos homok, felfelé finomodik; 7 — éles határ; 8 — keresztrétegzett kavicsos homok, felfelé egyre kavicsosabb, kevés iszaplepény alul, *Macaronichnus*; 9 — éles határ; 10 — bioturbált kavicsos homok, a kavicsok mérete lefelé csökken, egyre növekvő agyagrétegek az alsó részen; 11 — fokozatos átmenet; 12 — iszap- és nagyon finom homokrétegek váltakozása, halpikkelyek, sok növényi maradvány, nincs kavics

Рис. 5. Стратиграфическая колонка нижней осадочной толщи, обнажающейся в карьере песка восточнее с. Чокваомань. Стрелы показывают направления падения косой слоистости
1 — мощность; 2 — песок с облоками ракишек, в основе остатки гальки; 3 — поврхность эрозии; 4 — неслоистые пески, следы корней, в верхней части древние почвы, частично покрытые лигнитами и окаменелым удом; 5 — постепенный переход; 6 — галечниковые пески, имеющие горизонтальную слоистость, в верхних частях более мелкий; 7 — резкая граница; 8 — галечниковые пески, имеющие поперечную слоистость, в верхних частях все более галечниковые, внизу мало илистых лепешкообразных включений, *Macaronichnus*; 9 — резкая граница; 10 — биотурбированные галечниковые пески, размер галек уменьшается по направлению вниз, в нижней части все больше глинистых слоев; 11 — постепенный переход; 12 — чередование слоев ила и очень мелкозернистых песков, рыбная чешуя, много растительных детритов, отсутствие галек

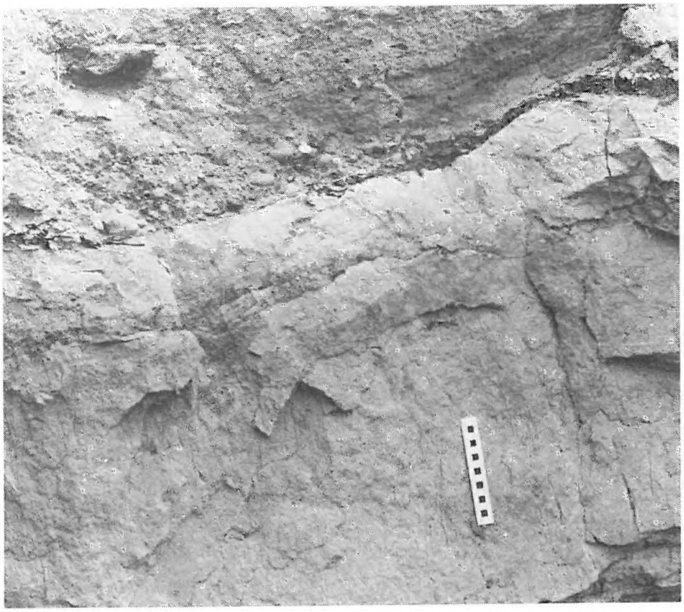


Fig. 6. Top of the lower sedimentary sequence in sand pit east of Csokvaomány. Light-colored interval is a probable paleosol. Dark-colored lignitic layer caps the light interval on right side of photograph. On left side of photograph, gravel conglomerate and pebbly, shell-bearing sand of the overlying sequence lie on the presumed paleosol. Dark near-vertical structures near centimeter scale are carbonized root structures

6. ábra. A Csokvaománytól keletre lévő homokgödör alsó üledékösszletének felső része. A világos színű réteg valószínűleg őstalaj. Sötét lignites réteg fedi a világos szintet a kép jobb oldalán. A fénykép bal oldalán a feltételezett őstalajon kavicskonglomerátum és kavicsos kagylóhéjas homok települ. Ezek a felsőbb üledékösszlet részei. A sötét, közel függőleges szerkezetek a centiméter-skála közelében meszesedett gyökérnyomok

Рис. 6. Верхи нижней осадочной толщи в карьере песка восточнее с. Чокваомань. Светлый интервал представляет собой вероятный палеосол. Темноцветный слой лигнита покрывает в виде шапки светлоцветный интервал на правой стороне фотографии. На левой стороне, предположенная ископаемая почва (палеосол) перекрывается галечниковыми конгломератами и песками с гальками и раковинами, относящимися к стратиграфически вышележащей толще. Темные, приблизительно вертикальные структуры недалеко от сантиметрового масштаба представляют собой обугленные корневые структуры

that maximum orbital velocities exceeded 1 m/s [Komar–Miller 1975]. Such velocities are produced at this depth by waves 1.3 to 2 m high [Clifton, in press]. The accumulation of fine mud suggests that the non-storm waves were no more than several tens of cm high and with periods in the range of 3 to 4 s [Clifton, in press].

With continued sedimentation the shoreline advanced seaward, the water shallowed, and the storm effects became increasingly common. At depths greater than about 3 m (again assuming no significant change in sea level) only the largest storms could stir the bottom, and the storm-generated currents were so infrequent that infaunal activity could mix the resulting deposits *(Fig. 7)*. A few outlines of dissolved bivalve shells confirm the presence of a molluscan fauna. Tubular burrows 1 to 1.5 cm (Fig. 7) in diameter suggest that the infaunal assemblage included burrowing decapods similar to present day *Callianassa* [WEIMER–HOYT 1964]. The preservation of a few discontinuous layers of clay up to 3 cm thick may reflect an infaunal aversion to burrowing through such very fine-grained sediment (Fig. 7).

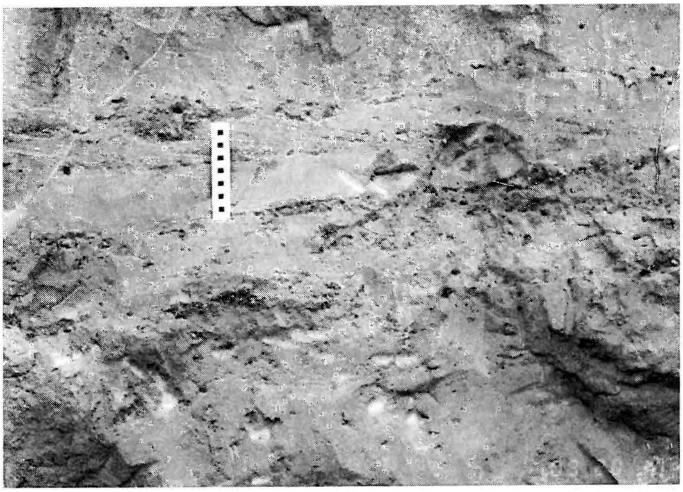


Fig. 7. Lower part of the lower sequence at sand pit east of Csokvaomány. Base of scale at contact between predominantly stratified sand (above) and predominantly bioturbated sand (below). Note large clay-lined, sand-filled burrow about 30 cm to lower right of scale

7. ábra. Az alsó összlet alsó része a Csokvaománytól keletre lévő homokgödörben. A centiméter-skála alja jelzi a határt az elsősorban rétegzett homok (fent) és az elsősorban bioturbált homok közt (lent). Figyeljük meg a skálától jobbra, lent mintegy 30 cm-re lévő homokkal tele, agyaggal tapasztott ásásnyomot

Рис. 7. Нижняя часть нижней толщи в карьере песка восточнее с. Чокваомань. Основание шкалы на контакте между преимущественно слоистыми песками (вверху) и преимущественно биотурбационными песками (внизу). См. крупный ход черви, заполненный песком и глинистым натеком на расстоянии примерно 30 см от нижнего правого конца масштаба

The section from 0–3 m on Figure 5 consists mostly of crossbedded pebbly sand *(Fig. 8)*. Most of the foresets dip in a generally westward, or offshore, direction (Fig. 2). Such an orientation suggests a dominance of rip currents. The cross-strata show no evidence of the "bundles" [ALLEN–HOMEWOOD 1984] that are produced by alternating tidal currents. The rip currents were probably generated during storms, and the bottom was stirred often enough to suppress the effects of bioturbation. Clusters of small sinuous, light-colored tubular burrows *(Macaronichnus)* occur within some of the crossbedded units. Such structures are produced today by errant polychaetes several tens of centimeters below the seafloor [Clifton–Thompson 1978], where they have a relatively high potential for preservation. A few lenticular clay drapes or flasers in the lower part of the crossbedded section represent the accumulation of suspended fine material on a rippled surface, perhaps in the aftermath of a storm.

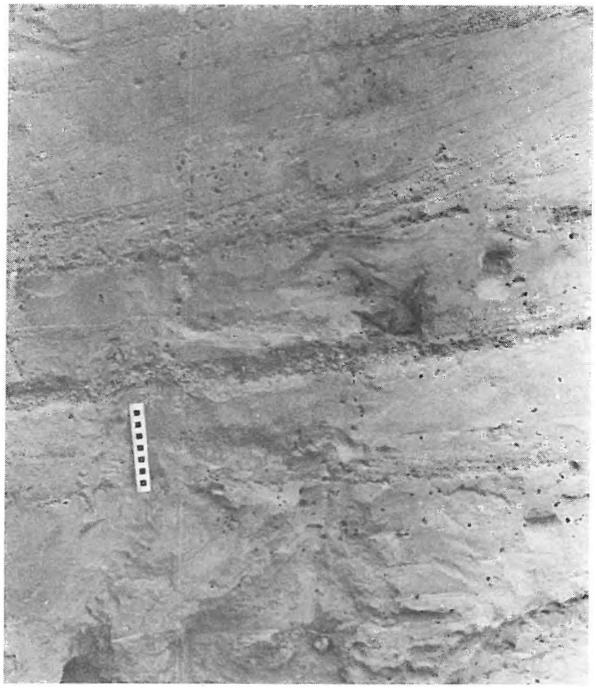


Fig. 8. Crossbedded pebbly sand and gravel layers, middle part of lower sequence in sand pit east of Csokvaomány. Base of centimeter scale marks transition to bioturbated sediment. Dark spots are modern-day insect borings

8. ábra. A Csokvaománytól keletre lévő homokgödör alsó üledékösszletének középső részén fekvő keresztrétegzett kavicsos homok- és kavicsrétegek. A centiméter-skála alja jelzi a bioturbált üledékbe való átmenetet. A sötét pettyek mai rovarok likai

Рис. 8. Косослоистые галечниковые пески и галечники, средняя часть нижней толщи в карьере песка восточнее с. Чокваомань. Основание сантиметрового масштаба представляет собой переход в осадок, нарушенный биотурбацией. Темные пятна являются современными дырками, пробуренными насекомыми

A pronounced change from crossbedding to planar-parallel lamination marks the top of the crossbedded section. Planar-laminated strata *(Fig. 9)* compose about 80 cm of the section that shows a general upward fining. At the top, the laminated section grades into a muddy, structureless sand that contains fossil root structures (Fig. 6). The planar-laminated section is interpreted as a beach foreshore deposit. Inverse size grading within some of the laminations

Fig. 9. Planar-laminated sand and gravel, upper part of lower sequence in sand pit east of Csokvaomány. Centimeter scale

9. ábra. Síkrétegzett homok és kavics. A Csokvaománytól keletre lévő homokgödör alsó összletének felső része. Centiméter-skála

Рис. 9. Плоскослойчатые пески и гальки, образующие верхи нижней толщи в карьере песка восточнее с. Чокваомань. Сантиметровый масштаб

(Fig. 10) supports this interpretation; inverse size grading is a common feature of modern foreshores, where it is produced by wave backwash [Clifton 1969]. The interface between beach foreshore deposits and the underlying nearshore sediment in a prograding sequence typically is marked by crossbedding that is inclined to seaward [Clifton et al. 1971]. Foresets in gravel immediately beneath the planar-laminated strata dip toward 230° (offshore) (Fig. 5). Such an orientation is consistent with the inferred paleogeographic setting for this deposit (Fig. 2).

The strata that overlie the foreshore facies are more enigmatic. The fossil root structures (which can be distinguished from decayed modern roots by their carbonization, limonitic encrustation, and infilling by sand) imply subaerial exposure. It is not clear whether this exposure is part of the progradation (e.g., as a backshore facies) or is related to subsequent tectonic (or eustatic) events.

A single discarticulated bivalve shell *(Pitaria)* in the muddy sand just above the foreshore facies suggests nearly normal marine salinity, but it is not clear whether the shell was deposited in a muddy embayment or was washed onto a subaerial platform behind the beach by a storm. The muddy sand is quite coarse and contains a few small scattered pebbles that could occur in either environment. At its top, the muddy sand is stained orange beneath a thin (6–10 cm) layer that is bleached white, a probable paleosol. Above this paleosol lies a thin (2–4 cm) lignite that is overlain by a discontinuous fissile mud bed that locally attains a thickness of 20 cm. This mud contains small gastropod shells (*Theodoxus*) and fragments of other mollusk shells, as well as ostracod casts. Also present are specimens of the foraminifera *Ammonia* sp., which by its sole occurrence indicates a brackish-water environment (P. Quinterno, 1984, personal communication). The mud probably represents deposition in a shallow marginal embayment. An erosional interval terminates the lower succession. Faunal remains in the lower succession are insufficient to specify the salinity. The trace fossils present could be produced by organisms that occur in a wide range of salinities. The inferred presence of meter-high storm waves is consistent with the basinal dimensions shown in Figure 2 [Clifton, in press].

The deposits in the upper succession, above the erosional surface, appear to have been deposited in an estuarine setting, as suggested by a fauna that indicates a brackish-water environment. The presence of *Congeria* indicates salinities in the range of 0.5 to 3.0 parts per thousand and the association of *Cardium*, *Theodoxus*, and *Pirenella* suggests salinities in the range of 3.0 to 16.5 parts per thousand.

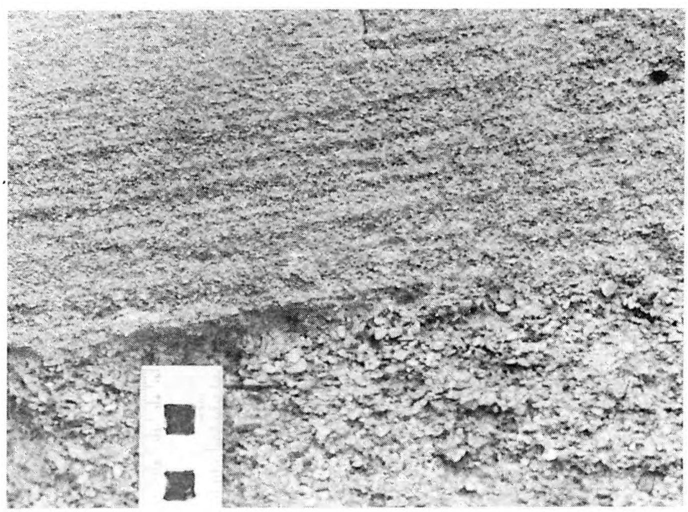


Fig. 10. Inverse textural grading in planar-laminated sand shown in Figure 9. Note sharp upper contacts to coarser laminae in section above centimeter scale

10. ábra. Inverz gradáltság a 9. ábrán bemutatott síkrétegzett homokban. Figyeljük meg a durvább laminák felé a hirtelen átmenetet, a centiméter-skála fölött

Рис. 10. Противоположная градация гранулометрического состава осадков и плоскослойчатых песках, показанных на *рис.* 9. См. резкий верхний контакт с более грубозернистыми пластинками в разрезе над сантиметровым масштабом

4. The Nekézseny deposit

The other nearshore sand and gravel deposit described here is exposed in a gravel pit about 200 m south of the highway, 2 km east of the village of Nekézseny (Fig. 1). The total length of the exposure in the pit approaches 100 m, and a total of about 28 m of section exists in the walls of the pit *(Fig. 11)*. The primary exposure *(Fig. 12)* is on a face that trends approximately north–south. The strata dip slightly to the east. A cut on the north side of the highway opposite the pit exposes sand that may be stratigraphically equivalent to that in the lower part of the quarry.

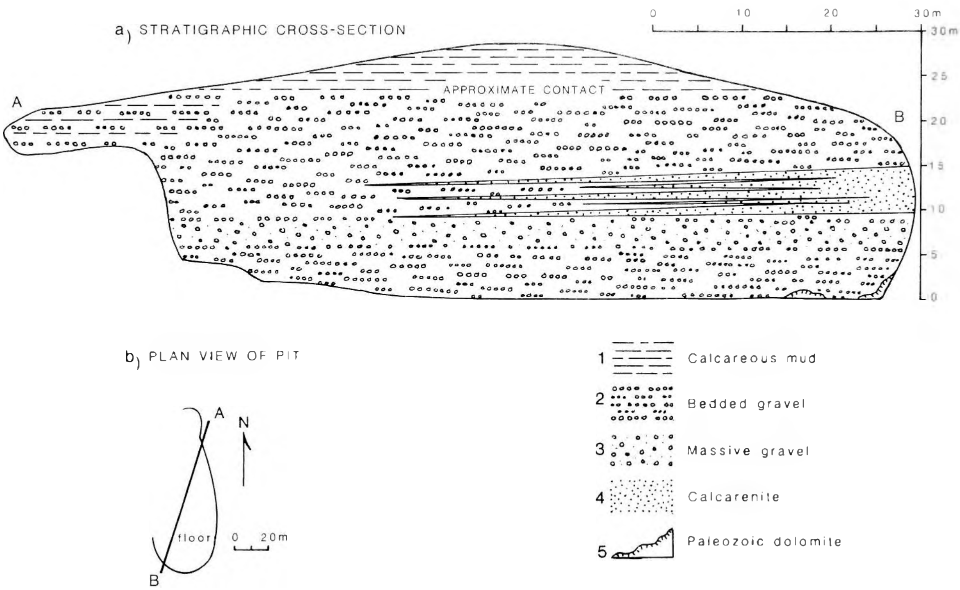


Fig. 11. Generalized sketch of section exposed in the gravel pit east of Nekézseny

11. ábra. A Nekézsenytől keletre lévő kavicsbánya által feltárt szelvény általános vázlata. a) Rétegtani keresztmetszet; b) A bánya alaprajza
1 — meszes iszap; 2 — rétegzett kavics; 3 — rétegzetlen kavics; 4 — mészhomok; 5 — paleozoos dolomit

Рис. 11. Обобщенная схема разреза галечникового карьера восточнее с. Некежень
a) Стратиграфический разрез; b) Смена шахты
1 — известковый ил; 2 — слоистые гальки; 3 — неслоистые гальки; 4 — известковые пески; 5 — палеозойские доломиты

The lower 21 m of section in the pit is predominantly gravel. The fauna in this section *(Table II)* indicate that it is part of the Egyházasgerge Formation (Fig. 2). The top of the section in the pit consists mostly of layered mud, and is part of the Garáb Formation (Fig. 2).

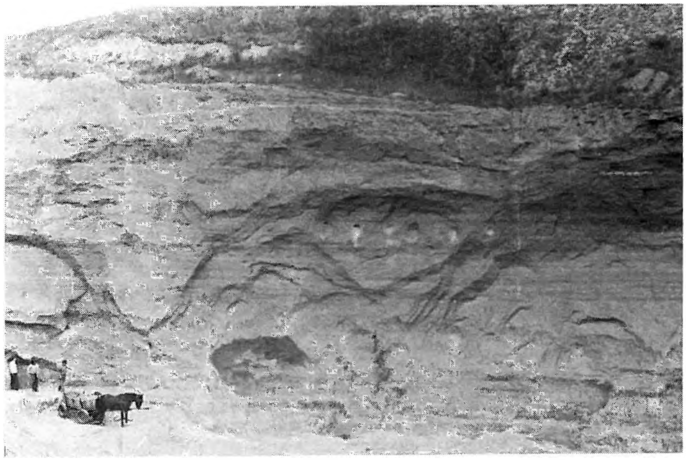


Fig. 12. Wall of gravel pit exposed east of Nekézseny

12. ábra. A Nekézsenytől keletre lévő kavicsbánya fala

Рис. 12. Стена галечникового карьера восточнее с. Некежень

Table II. Fossil assemblage in the Karpathian deposit exposed east of Nekézseny

II. táblázat. Kárpáti bentos faunaegyüttesek (Nekézseny)

Таблица II. Комплекс ископаемых остатков отложений карпатского яруса в обнажении к востоку от Некежения

Fossils: Porifera
Cliona sp
Mollusca
Bivalvia: *Lithophaga lithophaga* L.
Chlamys multistriata Poli
Chlamys opercularis hevesensis Schréter
Spondilus crassicosta Lam.
Anomia ephippium L.
Ostrea sp.
Gastrochaena sp.
?*Jouanettia* sp.
Arthropoda
Ostracoda
Cirripedia: *Balanus concavus* Bronn
Tentaculata
Bryozoa

The floor of the pit locally consists of a Paleozoic (Permian) carbonate rock. The borings of rock-boring clams *(Lithophaga)* cover the surface of this carbonate rock and confirm its exposure to a marine environment during the Miocene *(Fig. 13)*. The bedrock surface drops to the north more steeply than do the overlying strata. In the northwest part of the pit, the topographically lower parts of this surface are directly overlain by fine-grained micaceous quartzose sand, which in turn is abruptly overlain by carbonate-pebble conglomerate. The bedrock locally projects into this conglomerate on the northwest side of the pit, and is directly overlain by it on the southwest side. The *Lithophaga* borings in both cases are filled with quartz sand, suggesting that the bedrock was bored, covered by fine terrigeneous sand, then locally exhumed and subsequently covered by calcareous gravel. Barnacles on the parts of the surface that project into the gravel probably were extant during gravel deposition, which probably therefore occurred at intertidal or greater depths. In the southwest part of the pit a pavement of carbonate cobbles and boulders covers the lower parts of the surface *(Fig. 14)*. These clasts show less evidence of *Lithophaga* borings than does the surface itself.

Most of the sediment exposed in the pit consists of carbonate rock clasts that range in size from coarse sand to cobbles more than 10 cm across *(Fig. 15)*. The pebbles and cobbles range from subangular to well-rounded, whereas the sand-size material is predominantly subangular. The clasts lithologically resemble the Paleozoic carbonate rock at the base of the deposit, and siliciclastic components are conspicuously absent from the coarse sand and gravel. Pebbles displaying well-defined *Lithophaga* borings *(Fig. 16)* can be found throughout the section. In addition, as many as 5% of the pebbles show concave surfaces that may be scars of *Lithophaga* borings.

Fine-grained micaceous quartzose sand occurs as matrix material and as a few thin beds in the lower part of the gravel. This sand lithologically resembles that which underlies the gravel on the northern side of the quarry. Very fine silty,

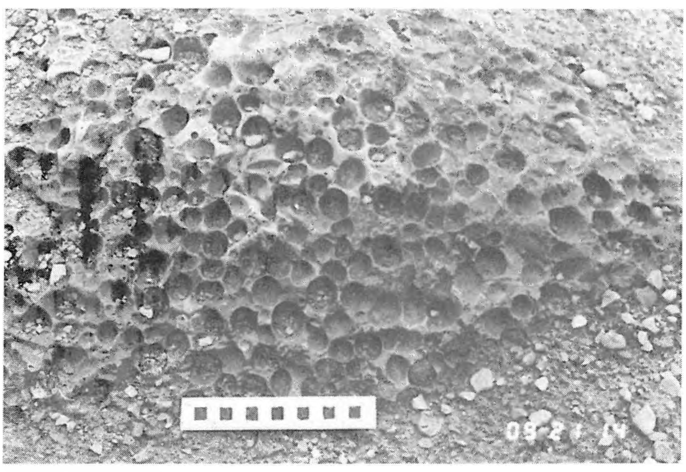


Fig. 13. Lithophaga borings on Paleozoic carbonate rock surface exposed in the lower part of the gravel pit east of Nekézseny

13. ábra. A Nekézsenytől keletre lévő kavicsbánya alján feltárt paleozoos karbonátkőzetben lévő *Lithophaga*-fúrások

Рис. 13. Дрырки, пробуренные каменоточцами *(Litophaga)* в палеозойской карбонатной породе, вскрытой в нижней части галечникового карьера восточнее с. Чокваомань

Fig. 14. Accumulation (near centimeter scale) of cobbles and boulders at the base of the conglomerate east of Nekézseny. Paleozoic carbonate rock surface ic exposed at base of wall to left of scale

14. ábra. Görgetegek és tömbök felhalmozódása (a centiméter-skála közelében) a Nekézsenytől keletre lévő konglomerátum alján. A paleozoos karbonátkőzet felszíne a fal alján van feltárva, a skálától balra

Рис. 14. Накопление (вблизи сантиметрового масштаба) галек и валунов в основании конгломератов восточнее с. Некежень. Поверхность палеозойской карбонатной породы обнажается в основании стены карьера налево от масштаба

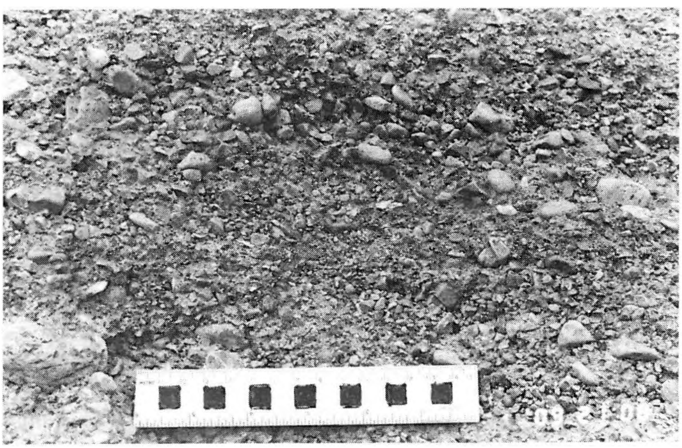


Fig. 15. Calcareous and dolomitic gravel in lowermost 5 m of section, pit east of Nekézseny. Note angularity of many clasts and suggestion of right-dipping imbrication

15. ábra. Mészkő- és dolomitkavics a szelvény legalsó öt méterén, a Nekézsenytől keletre lévő bányában. Figyeljük meg, hogy a törmelék jelentős része szögletes s jobbra dőlő imbrikációt sejtet

Рис. 15. Известковистые и доломитовые галечники в самых нижних 5 м разреза в карьере восточнее с. Некежень. См. угловатость большого количества обломков и предполагаемое правое падение чешуйчатости

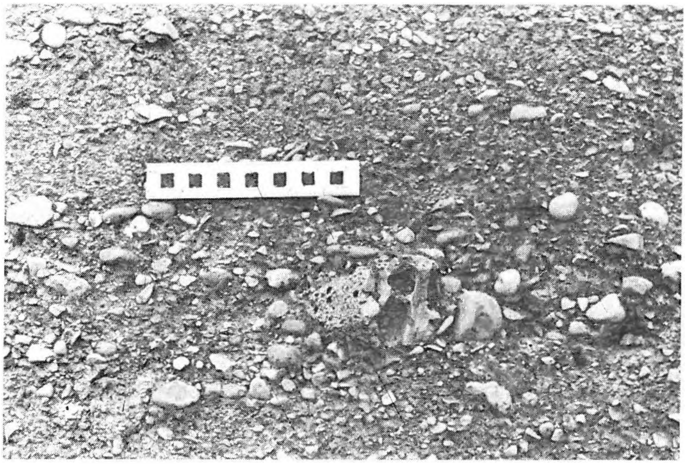


Fig. 16. Calcareous and dolomitic gravel, upper part of pit east of Nekézseny. Note variability of clast roundness and large *Lithophaga*-bored pebbles

16. ábra. Mészkő- és dolomitkavics a Nekézsenytől keletre lévő bánya felső részén. Figyeljük meg a törmelék gömbölyítettségének változó voltát és a nagy, *Lithophaga* által fúrt kavicsokat

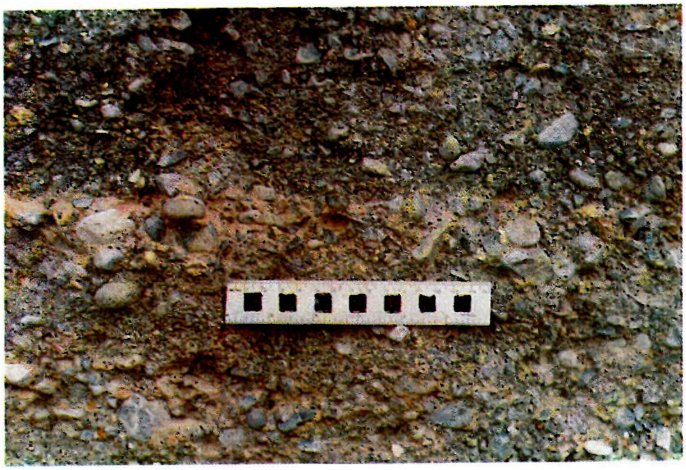
Рис. 16. Известковистые и доломитовые галечники в верхней части карьера восточнее с Некежень. См. изменчивость окатанности обломков и крупные гальки, пробуренные каменоточцами *(Litophaga)*

micaceous, predominantly carbonate sand and mud occurs in lenticular layers up to 4 cm thick and as matrix in the upper part of the gravel, particularly on the northern side of the pit. The muddy layers typically are unburrowed and show no evidence of desiccation cracks. Some rest atop laterally continuous layers of relatively coarse pebbles *(Fig. 17)*. Some of the thicker muddy layers show a well-defined textural grading into clay at their tops. This muddy sediment resembles the fine-grained material in the overlying Garáb Formation.

Shell fragments are common in the gravel. Nearly all are abraded, and most lie with concave sides up. Articulated *in-situ* bivalves were not seen. One fragment of *Siderastrea* coral was found in the upper part of the gravel.

The conglomerate generally displays distinct stratification *(Fig. 18)*. Most of the beds can be traced laterally for only a few meters. The sediment lacks the degree of sorting of sand and gravel into discrete laterally continuous beds that typifies some wave-worked gravel [Clifton 1973]. Lenticular calcarenite beds 10–20 cm thick exist, particularly in the middle part of the gravel section. Some of these beds show internal parallel-lamination or high-angle foreset bedding. Low-angle cross-stratification is evident in much of the conglomerate *(Fig. 19)*. The cross-strata dip at angles of 10° or less in units a few tens of cm thick.

A striking feature of the gravel is a textural grading within many of the gravel beds. Such beds typically are a few cm thick; they are composed of fine limestone gravel at the base that grades upward into calcarenite at the top *(Fig.*



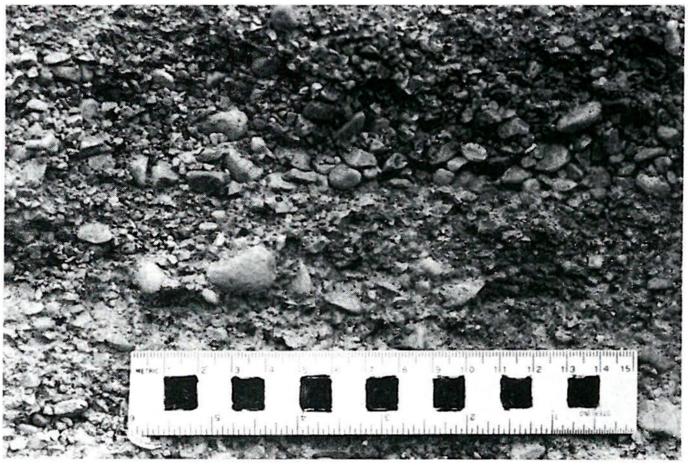


Fig. 17. Muddy (very fine silty sand) layer in gravel; upper part, north end of pit east of Nekézseny. Note layer of somewhat coarser pebbles immediately beneath fine layer

17. ábra. Iszapos (nagyon finom aleuritos homok) réteg a kavicsban, a Nekézsenytől keletre lévő bánya északi végének tetején. Figyeljük meg azt a valamivel durvább kavicsokból álló réteget, amely közvetlenül a finom réteg alatt van

Рис. 17. Илистый (весьма тонкозернистые алевритистые пески) слой в галечниках в верхней части северного конца карьера восточнее с. Некежень. См. слой несколько более грубозернистых галечников непосредственно под тонкозернистым слоем

Fig. 20. A) Graded layer in calcareous and dolomitic gravel, pit east of Nekézseny. Note absence of matrix in gravel at base of layer (cm scale).
B) Low-angle foresets composed of graded layers. Yellow colour due to quartzose sand matrix (cm scale)

20. ábra. A) Gradált réteg a mészkő- és dolomitkavicsban, kavicsbánya Nekézsenytől keletre. Figyeljük meg, hogy a réteg alján nincs mátrix a kavicsban
B) Gyengén dőlő, osztályozott rétegekből álló nyúlványok. A sárga színt a kvarcos homok mátrix okozza (cm skála)

Рис. 20. А) Проявление сортированности гранулометрического состава в известковистых и доломитовых галечниках в карьере восточнее с. Некежень. См. отсутствие цемента в галечниках в основании слоя (сантиметровый масштаб)
В) Выходы слоев с небольшим углом наклона и в сортированных осадках. Желтый цвет обусловлен цементом, сложенным кварцевыми песками (сантиметровый масштаб)

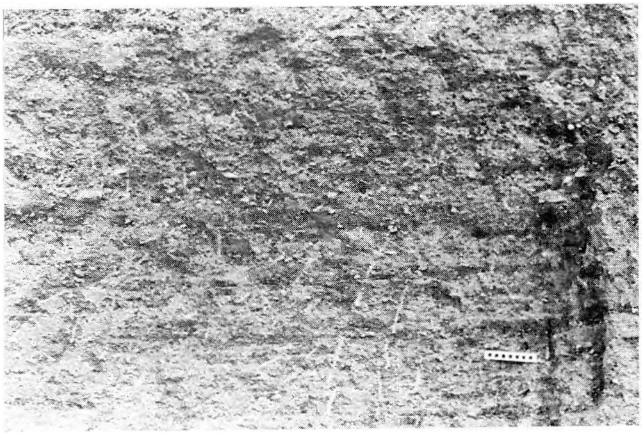


Fig. 18. Stratification in gravel, pit east of Nekézseny. Centimeter scale

18. ábra. Rétegződés a kavicsban. Kavicsbánya Nekézsenytől keletre. Centiméter-skála

Рис. 18. Слойчатость в галечниках в карьере восточнее с. Некежень. Сантиметровый масштаб

Fig. 19. Low-angle cross-stratification in lowermost 5 m of section, pit east of Nekézseny

19. ábra. Kishajlású keresztrétegzettség a szelvény alsó öt méterén. Kavicsbánya Nekézsenytől keletre

Рис. 19. Косая слоистость с небольшим углом наклона в низах самых нижних 5 м разреза карьера восточнее с. Некежень

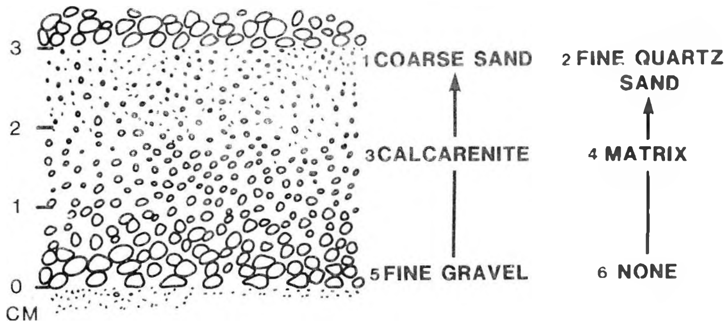


Fig. 21. General character of graded cycles in lowermost 5 m of gravel, pit east of Nekézseny

21. ábra. A gradált ciklusok általános jellege a kavics alsó öt méterén, a Nekézsenytől keletre lévő kavicsbányában.
1 — durva homok; 2 — finom kvarchomok; 3 — mészhomok; 4 — mátrix; 5 — apró kavics; 6 — hiány

Рис. 21. Общий вид циклов отсортированности осадков в самых нижних 5 м галечников в карьере восточнее с. Некежень
1 — грубые пески; 2 — мелкозернистые кварцевые пески; 3 — известковые пески; 4 — матрица; 5 — мелкие гальки; 6 — отсутствие

20). In the lower part of the pit, the fine-grained quartzose sand commonly forms a matrix to the coarse calcarenite at the top of a graded bed *(Fig. 21)*. The fine gravel in the lower part of such beds is matrix-free. The graded beds form depositional cycles in much of the gravel and compose many of the low-angle foresets in the unit.

Biogenic structures are present in the gravel in the form of clay-lined tubes *(Fig. 22)*. Most of these are 1–2 cm in diameter. The largest have a central, gravel-filled core 3 cm across enclosed by a 1-cm-thick rim of clay-matrixed gravel. The tubes are somewhat sinuous, and most are subvertical. Branches were not observed but may exist. One enlarged "turn-around chamber" occurs at a right-angle turn in a burrow. The burrows resemble in many ways those produced today by decapods such as *Callianassa.*

Directional features within the gravel are remarkably diverse. The low-angle foresets in the gravel dip primarily toward the southeast, whereas the high-angle foresets dip mostly toward a sector that ranges from northeast to northwest. Measurement of the long axes of 50 pebbles in the lower part of the unit showed a well-defined south–southeast, north–northwest trend. A similar orientation was visually evident on a bedding surface exposure high in the pit. Many of the pebbles in the conglomerate show a clear imbrication *(Fig. 23)*. The direction of imbrication is variable. In the lower part of the quarry the predominant inclination direction seems to be toward the south, whereas in the upper part it seems to be predominantly toward the north.

Lateral trends in clast size are evident within the gravel. Measurement of the long axes of the 25 largest pebbles within a m^2 surface of the same beds 30 m apart showed a clear decline in size (5.8 cm to 3.7 cm) in a northeasterly

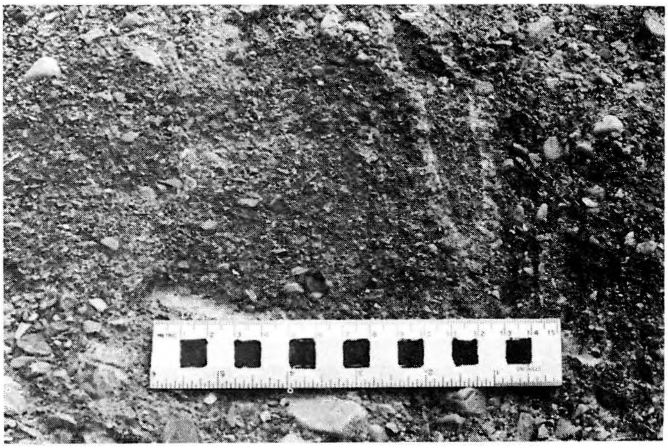


Fig. 22. Clay-lined burrow in gravel, pit east of Nekézseny. Note filling by carbonate sand. Cm scale

22. ábra. Agyaggal tapasztott ásásnyomok a kavicsban, a Nekézsenytől keletre lévő bányában. Figyeljük meg a karbonáthomokos kitöltést. Cm skála

Рис. 22. Дырка, пробуренная организмами в галечниках, изнутри покрытая пленкой глины в карьере восточнее с. Некежень. См. заполнение карбонатным песком. См масштаб

Fig. 23. Well-defined pebble imbrication (dipping to the right). Lower 5 m of gravel, pit east of Nekézseny. Note graded units

23. ábra. Határozott kavics-imbrikáció (dőlés jobbra). A kavics alsó öt métere, kavicsbánya Nekézsenytől keletre. Figyeljük meg a gradált egységeket

Рис. 23. Выраженная чешуйчатость галек (с наклоном направо). Нижние 5 м галечников в карьере восточнее с. Некежень. См. отсортированные единицы direction. A similar decrease probably exists in the upper part of the gravel, although it is impossible to trace the same set of beds from the southern part of the exposure to the northern part. In the upper part of the quarry, pebbles commonly exceed 5 cm at the southern end of the exposure, whereas 60 m to the north, pebbles larger than 5 cm are uncommon in the same general part of the section. Local concentrations of coarse pebbles, however, do exist in the northern part of the quarry.

Unlike the Miocene deposit exposed east of Csokvaomány, the gravel in the pit east of Nekézseny does not display a vertical sequence that can be readily

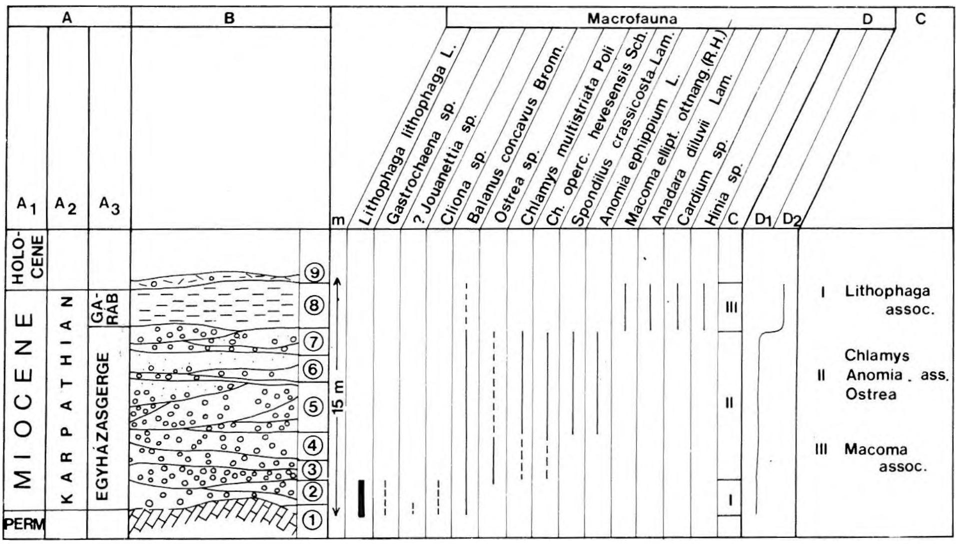


Fig. 24. Stratigraphic variation in macrofauna, gravel pit east of Nekézseny.
A — Cronostratigraphy: A_1 — age, A_2 — stage, A_3 — formation; B — Lithofacies; C — Assemblages; D — Environment: D_1 — eulitoral, D_2 — sublitoral; 1 — limestone; 2 — gravel with limestone blocks; 3 — sandy coarse gravels; 4 — gravelly sand; 5 — sand including coarse gravels; 6 — gravelly sand; 7 — sandy coarse gravels; 8 — silty clay; 9 — Holocene detritus

24. ábra. Rétegtani változás a makrofaunában, kavicsbánya Nekézsenytől keletre.
A — Kronosztratigráfia: A_1 — kor, A_2 — emelet, A_3 — formáció; *B* — Litofácies; *C* — Faunaegyüttesek; *D* — Környezet: D_1 — eulitorális, D_2 — szublitorális; 1 — mészkő; 2 — mészkőtömbös kavics; 3 — homokos durva kavics; 4 — kavicsos homok; 5 — durva kavicsos homok; 6 — kavicsos homok; 7 — homokos durva kavics; 8 — kőzetlisztes agyag; 9 — fiatal törmelék

Рис. 24. Стратиграфическое изменение в макрофауне в галечниковом карьере восточнее с. Некежень
А — Хроностратиграфия: A_1 — возраст, A_2 — ярус, A_3 — формация; В — Литофациальные; С — Фаунистические сообщества; D — Среда; D_1 — эвлиторальная; D_2 — сублиторальная; 1 — известняки; 2 — гальки с известняковыми блоками; 3 — песчаные грубые гальки; 4 — галечные пески; 5 — грубогалечные пески; 6 — галечные пески; 7 — песчаные грубые гальки; 8 — алевритовые глины; 9 — молодые обломки

interpreted in terms of changes in depositional environment. The uppermost gravel in the pit closely resembles that exposed 21 m stratigraphically below at the base of the pit. Environmentally significant vertical variation in the section may be limited to subtle differences in matrix composition, changes that are associated with lateral variations, and the transition to the finer-grained Garáb Formation near the top of the pit. Stratigraphic variation in the macrofauna assemblage *(Fig. 24)* may also be significant.

The basal 5 m of gravel exposed in the pit (Fig. 13) is typically well-bedded. Burrows are rare and southeast-dipping low-angle foresets in units 0.2–0.6 m thick are particularly well displayed on the southwestern part of the pit wall. The lower part of this section contains much very fine quartzose sand as matrix and thin beds, particularly near the base. The aforementioned measured decrease in pebble size toward the northeast occurs in this part of the section.

The section from 5 to 8 m above the base shows very little internal structure. Local brown patches of iron oxidation on the order of 5–10 cm across are common. On fresh exposure, many of these can clearly be seen in association with tubular burrows like those described in a preceding paragraph. It is probable that the structureless aspect of this part of the section results from intense bioturbation. A few very rare lenses of crossbedded calcarenite in the otherwise structureless sandy gravel suggest that the gravel was probably originally layered much like that immediately above and below. The middle part of the structureless section contains a laterally persistent layer of scattered coarse (5–8 cm) rounded carbonate rock clasts.

The section from 8–13 m above the base of the gravel contains beds and lenses of calcarenite. This sand is composed mostly of subangular carbonate fragments between 0.5 and 1.0 cm in diameter. Shell fragments are a common component, and quartzose sand, abundant in the lower part of the gravel, is almost non-existent. The lateral distribution of the calcarenite differs within the pit. On the nearly inaccessible southwestern wall, sand dominates the section, but it largely lenses out within a few tens of meters to the northeast. Calcarenite beds are generally absent in equivalent section at the northern part of the pit. In the central part of the quarry, burrows are particularly evident in this part of the section.

The uppermost 7–8 m of gravel resembles that in the lowermost 5 m. Quartzose sand in this upper section is less abundant and finer than that near the base of the gravel. Discrete layers of very fine-grained silty sand and mud are common in the northern part of the pit but absent in southern exposures where similar fine sediment is present only as matrix. As in the lower 5 m of section, decimeters-thick units of foresets defined by graded gravel layers dip gently toward the southeast.

The contact of the gravel with the overlying Garáb Formation lies within a 3.5–4 m interval that is covered by overburden. Above this interval, about 3 m of the Garáb Formation is exposed at the top of the pit. This unit consists of micaceous silty mud that contains isolated one-pebble-thick layers of limestone granules and pebbles less than 1 cm across and shell fragments. Shell fragments are also abundantly scattered within the muddy section (the *Macoma* association, Fig. 24).

The deposits in the gravel pit are not so readily explained as those in the sand pit east of Nekézseny. Many lines of evidence suggest deposition in very shallow water, but the specific depth range and the origin of the observed features in the deposit are rather speculative.

The macrofauna occur in three distinct associations. The lowermost association (Fig. 24) is characterized by many bivalve specimens, particularly *Lithophaga*. The association is confined to the proximity of the Permian carbonate rock surface, which is so densely covered by borings as to limit the available space for other rock-clinging forms (such as oysters or barnales). Most of the borings are those of *Lithophaga; Cliona* traces exist but are relatively rare. The association is autochthonous and lacks exotic elements. All species could have lived together along a rocky limestone or dolomite shoreline.

The main body of the calcareous gravel contains an allochthonous macrofaunal association (Fig. 24) that is characterized by the genera *Chlamys, Anomia* and *Ostrea*. The shells occur predominantly as worn fragments, commonly riddled by boring organisms (such as *Cliona* and *Balanus*). This and the relatively high density of the shells indicate post-mortem transportation. The general ecologic coherence of the assemblage suggests that the fauna coexisted in a shallow wave-swept sandy environment and accumulated near their living site.

The third *(Macoma)* macrofaunal association occurs in the Garáb Formation (Fig. 24). It is characterized by a relatively low fossil density, a small percentage of shell fragments, and many single and a few paired bivalve shells. The assemblage is para-autochthonous; most of the species could have co-existed in a silty or clayey substrate of a shallow sea.

The physical processes that controlled deposition of the gravel and sand are not unequivocally clear. The angularity of the clasts implies a rather limited abrasional history (particularly upon consideration of the softness of carbonate rock relative to siliceous clasts). The variability of imbrication direction within the gravel suggests paleocurrents from diverse directions.

The water depth was probably no more than a few meters. The high degree of lateral variability of the sediment in the quarry suggests rapid facies change of the type commonly found in very shallow water. The abundance of large pebbles throughout the gravel likewise suggests shallow depths. Threshold curves indicate a requirement for wave-generated oscillatory currents of at least 2 m/s to move a quartz sphere 5 cm in diameter [Komar–Miller 1975]. Many of the limestone and dolomite clasts in the gravel are probably equivalent hydraulically to such a quartz sphere, and currents of 2 m/s accordingly would seem fairly common. Airy wave theory provides a basis for estimating the combinations of wave height, wave period, and water depth that will produce this velocity [Clifton–Dingler 1984]. *Figure 25* shows these combinations under the assumption that the only current present is due to passing waves. At a water depth of 10 m oscillatory currents equivalent to 2 m/s would require waves on the order of 4–5 m high—an unlikely amplitude given the paleogeo-

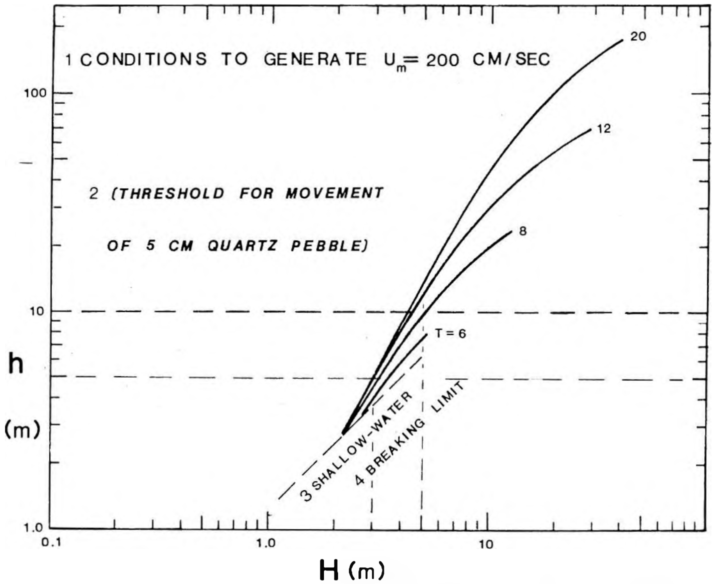


Fig. 25. Combinations of wave height, wave period and water depth required to initiate movement of a quartz pebble 5 cm in diameter

25. ábra. Az öt centiméter átmérőjű kvarckavics megmozdításához szükséges kombinációja a hullámmagasságnak, hullámperiódusnak és vízmélységnek
1 — U_m = 200 cm/s áramlást létrehozó körülmények; 2 — (5 cm-es kvarckavics megmozdításának küszöbértéke); 3 — sekélyvíz; 4 — hullámtörés határa

Рис. 25. Сочетание высоты волн, их периодичности и глубины водоема, необходимое для перемещения кварцевой гальки диаметром 5 см
1 — условия, создающие приток U_m = 200 см/сек; 2 — (граничное значение, необходимое для сдвижения кварцевой гальки размером 5 см); 3 — мелководье; 4 — граница разлома волн

graphic setting (Fig. 4). At a water depth of 5 m somewhat more reasonable waves (on the order of 3 m high) would be required.

Many of the specific features in the gravel are difficult to explain. The graded low-angle foresets that occur in much of the gravel are a good example. It is not clear whether these layers result from a specific event such as a storm or flood (if the gravel represents the seaward part of a small fan-delta), or from the lateral migration of large ripples. Wave ripples in gravelly sediment near rocky shorelines where the sand supply is limited or in bays where waves are small are known to have finer material concentrated on their crests [Inman 1957]. If such ripples migrated laterally during active sedimentation, the resultant climbing-ripple structure might resemble the graded foresets.

The inconsistency of directional features is also difficult to interpret. High-angle foresets in the calcarenite dip in a generally northerly direction, whereas low-angle foresets in the gravel dip predominantly toward the southeast. Grain size variations are inconsistent (a northerly fining in the lower and upper parts of the gravel, a northerly coarsening in the central part of the section containing the calcarenite), as are pebble orientation patterns (northwest–southeast long axis trend and variable imbrication direction). Such directional variability suggests that different processes influenced this sediment. The directional data, the lithologic homogeneity of the clasts, as well as the abundance of shell fragments and *Lithophaga*-bored clasts throughout the deposit, suggest that the deposit is not a fan-delta composed of fluvial detritus. Similarly it does not appear to be a simple beach–nearshore deposit as typified by the Csokvaomány example.

Perhaps the most reasonable interpretation is that the gravel accumulated at the foot of a rocky sea cliff of substantial relief under conditions of slowly rising sea level. The lack of pronounced vertical change in the 20 m of gravel suggests that sediment accumulated on the sea floor at about the same rate as sea level rose. Possibly the volume of carbonate rock detritus was augmented by a fluvial fan-delta contribution. The regional paleogeography (Fig. 4) suggests that the sea cliff was on the north side of a small island (perhaps a karstic feature) composed of Permian carbonate rock.

Under this interpretation, the initial gravel deposition occurred in the general proximity of a shoreline to the north. Quartzose sand associated with this shoreline is intermixed with the lowermost part of the gravel. As sea level rose and the shoreline retreated to the north, the amount of available siliciclastic sand near the island diminished. Subsequently, finer-grained siliciclastic sediment formed the matrix of the gravel, and, in quieter water away from the island shore, accumulated in discrete beds. When sea level inundated the island, gravel deposition ceased, and the fine-grained sediment of the Garáb Formation began to accumulate on the sea floor.

Such an interpretation is consistent with some of the directional features. It would explain the northerly decrease in pebble size. The clean carbonate sand that lenses out to the north in the central part of the section can be explained as a beach or near-beach deposit that, like some modern beaches, changed from sand to gravel a short distance offshore. The north-dipping high-angle foresets in this sand accordingly could be either "toe-of-beach" or rip current structures.

The origin of southeasterly dip of the low-angle foresets in the gravel remains enigmatic. Such a direction intuitively seems improbable in this paleogeographic setting for upslope (northeast) climbing wave ripples. Conceivably the foresets might reflect deposition on the flank of a localized accumulation of gravel such as a small fan-delta. The grading in the foresets could be due to discrete depositional events (such as a storm or flood), or to the climbing of wave-formed ripples across a southeast-facing, gently-stepped surface.

5. Conclusions

The paleoenvironmental setting of the nearshore deposits described here is generally similar—both accumulated near the shoreline of a narrow Miocene seaway. The lithologic character of the two deposits, however, differs markedly.

Their difference is probably due more to contrasts in the rate of sea level change relative to sedimentation rate and in the textural composition of the available sediment than to differences in the physical environment.

One deposit, part of the Salgótarján Formation, appears to be a prograding shoreline deposit. A variety of depositional environments—inner shelf, nearshore, foreshore, and backshore—are compressed into a shallowing-upward sequence less than 7 m thick. Storm deposits are recognizable in the lower part of the section. The sedimentary structures and directional features are nicely consistent with the reconstructed paleogeography. Development of the progradational sequence terminated with a renewed transgression of the sea.

The second deposit, part of the Egyházasgerge Formation, is not so readily interpreted, despite being very well exposed over a laterally and vertically extensive gravel pit face. The succession here appears to have accumulated during an episode of marine transgression in which the rate of gravel deposition seems to have been more or less equivalent to the rate of sea level rise. The gravel is apparently derived from a Paleozoic carbonate rock upland immediately to the south, possibly even from shoreline erosion of an island formed in part by karstic processes.

Many of the features in the gravelly deposit can be explained in terms of a marine transgression in which an initially adjacent siliciclastic shoreline retreated to the north. As a consequence of this shift, the siliciclastic sediment at the Nekézseny gravel pit became progressively finer with time. Concurrently, calcareous and dolomitic sand and gravel accumulated adjacent to the upland until it was inundated and deposition of silt and clay then prevailed at this site.

REFERENCES

ALLEN P. A., HOMEWOOD P. 1984: Evolution and mechanics of a Miocene tidal sand wave. Sedimentology, **31**, 1., pp. 63–81

BALOGH K. 1964: Geologischen Bildungen des Bükk-Gebirges. MÁFI Évkönyv (Annales Inst Geol. Publ. Hung.), **48**, 2, 719 p. Budapest

BOHN-HAVAS M. 1978: Biostratigraphical and paleoecological evaluation of Miocene macrofauna on the lignite-exploration area of Mikófalva (in Hungarian). Report. 60 p. MÁFI Database, Budapest

CLIFTON H. E. 1969: Beach lamination–nature and origin. Marine Geology, **7**, 6, pp. 553–559

CLIFTON H. E. 1973: Pebble segregation and bed lenticularity in wave-worked versus alluvial gravel. Sedimentology **20**, 1, pp. 173–187

CLIFTON H. E. in press: Interpretation of paleoenergy levels from sediment deposited on ancient wave-dominated shelves. Can. Soc. Petroleum Geologists Memoir

CLIFTON H. E., DINGLER J. H. 1984: Wave-formed structures and paleoenvironmental reconstruction. Marine Geology, **60**, 1–4, pp. 165–198

CLIFTON H. E., HUNTER R. E., PHILLIPS R. L. 1971: Depositional structures and processes in the high-energy nonbarred nearshore. J. Sedimentary Petrology, **41**, 3, pp. 651–670

CLIFTON H. E., THOMPSON J. K. 1978: *Macaronichnus segregatis* – a feeding structure of shallow marine polychaetes. J. Sedimentary Petrology, **48**, 4, pp. 1293–1302

CSÁSZÁR G., HAAS J., HALMAI J., HÁMOR G., KORPÁS L. 1982: The role of middle and late Alpine tectonic phases in the geological evolution of Hungary (in Hungarian). MÁFI Évi Jel. az 1980. évről (Annual Report of the Hung. Geol. Inst.), pp. 509–516

HÁMOR G. 1980: The age of Neogene tectonic phases in the Paratethys realm. 26ᵉ Congrés Géol. Internat. (Res.), Paris, 1, p. 384
HÁMOR G. 1983: The quantitative methods of palaeogeographical reconstruction. MÁFI Special Papers 2, 70 p. Budapest
HÁMOR G. 1984: Paleogeographic reconstruction of Neogene plate movements in the Paratethyan realm. Acta Geol. Hung. **27,** 1–2, pp. 5–21
HÁMOR G., HALMAI J. 1975: Palaeogeographical map of the Miocene of northern Hungary (in Hungarian). MÁFI Database, Budapest
HARMS J. C., SOUTHARD J. B., WALKER R. G. 1982: Structures and sequences in clastic rocks. S.E.P.M. Short Course No. 9, Soc. Econ. Paleontologists Mineralogists, Tulsa, Okla., 249 p.
INMAN D. L. 1957: Wave-generated ripples in nearshore sands. Tech. Memo. Beachs Eros. Bd. U.S., No. 100
KOMAR P. D., MILLER M. C. 1975: Sediment threshold under oscillatory waves. Proc., 14th Conf. on Coastal Engr., pp. 756–775
RADÓCZ GY. 1975: Explanations for the 200,000 scale geological map series of Hungary (in Hungarian). 257 p. MÁFI, Budapest
SCHRÉTER Z. 1929: Mining-geological description of the lignite deposits of counties Borsod and Heves (in Hungarian). MÁFI, 394 p. Budapest
SCHRÉTER Z. 1945: Geologische Aufnahmen im Gebiete von Uppony ferner im Gebiete von Putnok (in Hungarian, with German abstract). MÁFI Évi Jelentés az 1941–42. évről (Annual Report of the Hung. Geol. Inst.), pp. 161–237, Budapest
SCHRÉTER Z. 1954: Relevé géologique dans les environs de Szilvásvárad (in Hungarian, with French abstract). MÁFI Évi Jelentés az 1952. évről (Annual Report of the Hung. Geol. Inst.), 135 p. Budapest
WEIMER R. J., HOYT J. H. 1964: Burrows of *Callianassa major* SAY, geologic indicators of littoral and shallow neritic environments. J. Paleontology, **38,** 4, pp. 761–767

ELTÉRŐ TÍPUSÚ HOMOK- ÉS KAVICSÜLEDÉKEK AZ ÉSZAK-MAGYARORSZÁGI MIOCÉNBŐL

H. Edward CLIFTON, BOHNNÉ HAVAS Margit és MÜLLER Pál

A vizsgált üledéksorok az Egercsehi–Ózdi árokban keletkeztek. Itt az eggenburgi–ottnangi üledékek két teljes ciklust képviselnek, melyek közé a Gyulakeszi Riolittufa Formáció települ. E fölött a felső ciklushoz tartozó Salgótarjáni Barnakőszén Formáció homokos, aleuritos és agyagos, lignit-tartalmú üledékei települnek. E formációba tartozó üledéksort tár fel a Csokvaománytól K-re lévő kis homokgödör. A szelvény alsó része progradáló parti üledéknek tekinthető, iszap-homokrétegek felfelé fokozatosan keresztrétegzett kavicsba mennek át, melyet laminált homok, gyökérnyomos iszap, vékony lignitzsinór és csigás iszap takar, s a sor eróziós felszínnel zárul. A kavics és a laminált homokréteg határa az egykori tengerszintet jelzi. A sor egyes tagjai a progradáció során egyre sekélyebbé váló környezet sávjában ülepedhettek le. A fauna a Salgótarjáni Barnakőszén Formációra utal, de nem ad felvilágosítást a sótartalomra. Csupán az eróziós felszín felett települő, lagúna-eredetű üledékekben találhatók 0,5–3,0 illetve 3,0–16,5‰-os sótartalomra jellemző alakok vagy együttesek.

A kárpáti–badeni korszakban is két üledékciklust figyelhetünk meg. Az alsó, kárpáti korú ciklusba tartozik az Egyházasgergei Formáció. Ennek része a Nekézsenytől keletre, egy kavicsbányában feltárt kavicsösszlet. A fekü paleozoos karbonát-felszínt Lithophaga-kagylók tömegei fúrták meg. Erre 21 m mészkő- és dolomitanyagú kavics települ, részben közvetlenül, részben kvarchomok közbetelepüléssel. A fauna tengeri üledéket jelez. A nagyobb kavicsokat mozgató oszcilláló vízmozgást legfeljebb néhány méter mély vízben képzelhetjük el, az adott ősföldrajzi helyzetben. A szemnagyságban mutatkozó rendszeres változás arra szorítkozik, hogy a sziliklasztkomponens felfelé finomodik (lent finom homok, feljebb aleuritos igen finom homok, majd agyag). Feltesszük, hogy az üledék egy kiemelt terület (talán egy sziget) lábánál rakódott le, a transzgresszióval lépést tartó üledékképződéssel. Így a helyi eredetű mészkő–dolomit-törmelék nagyjából azonos vízmélységet jelez a szelvényben. Az eredetileg szomszédos sziliklasztos partvidék visszahúzódása az ilyen komponens finomodásában mutatkozik meg. A karbonátos sziklasziget teljes elöntése után a kavicsképződés és ülepedés megszűnt, s a Garábi Slir Formáció finomszemű üledékei zárták a kárpáti korú üledékképződést.

ОТЛИЧАЮЩИЕСЯ ТИПЫ ПЕСЧАНЫХ И ГАЛЕЧНЫХ ОСАДКОВ ИЗ МИОЦЕНОВЫХ ОБРАЗОВАНИЙ СЕВЕРНОЙ ВЕНГРИИ

Г. Эдвард КЛИФТОН, Маргит БОН-ХАВАШ и Пал МЮЛЛЕР

Исследованные осадочные породы происходят из канав Эгерчехи и Озда. Здесь осадки эггенбурга–оттнанга представляют собою два полных цикла, среди которых залегают образования Дьюлакеси Риолитово–Туфовой Формации. Над ними лежат относящиеся к верхнему циклу песчаные, алевритовые и глинистые осадки, а также содержащие лигнит, Шалготарянской Буроугольной формации. Разрез осадочных образований, относящихся к этой формации, вскрыт в небольшой песчаной яме, находящейся на восток от Чокваомань. Нижнюю часть разреза можно рассматривать как перемещавшиеся береговые осадки, илисто–песчаные слои вверх по разрезу постепенно переходят в поперечно слоистые гальки, которые покрыты ламинированным песком, илом со следами корней, тонкими шнурами лигнита и ракушечным илом, разрез заканчивается поверхностью эрозии. Граница галек и слоя ламинированного песка обозначает прежний уровень моря. Отдельные члены разреза во время продвижения отлагались в полосе все более мелкого окружения. Фауна указывает на Шалготарянскую Буроугольную формацию, но не дает объяснения относительного содержания солей. Только в осадочных образованиях лагунового происхождения, находящихся над поверхностью эрозии, можно встретить особи и комплексы, характерные для 0,5–3,0 и 3,0–16,5‰-ного солесодержания.

В карпатско–баденском периоде времени также наблюдаются два цикла осадконакопления. Нижний, карпатского возраста, и представлен Эдьхазашгергейской Формацией. Часть этой формации представлена толщей галек, вскрытой в большом галечниковом карьере на восток от Некежень. Лежащая в подошве поверхность палеозойских карбонатов пробурена массами представителей раковин Lithophaga. На них налегают в мощности 21 м известняковые и доломитовые гальки частично непосредственно, частично с включениями кварцевого песка. Фауна указывает на осадки морского происхождения. Колеблющееся движение вод, передвигавших более большие гальки, мы можем представить для вод в несколько метров глубиной в бывшем палеогеографическом положении. Систематическое изменение, наблюдаемое в размере зерен, показывает, что силикластические компоненты в направлении вверх становятся мельче (внизу мелкий песок, выше алевритовый очень мелкий песок, затем глина). Предполагаем, что осадки отложились у подножья одного приподнятого участка (может быть острова) во время осадкообразования, проходившего вместе с трансгрессией. Таким образом, известняково–доломитовые обломки местного происхождения в разрезе большей частью указывают на идентичные глубины воды. Отступление первоначально соседней силикластовой береговой территории проявляется в таком измельчении компонентов. После полного погружения в воды карбонатового скалистого острова прекратилось образование галек и накопление осадков, и процесс осадкообразования карпатского возраста завершили тонкозернистые осадки Гарабской Шлировой Формации.