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Quaternary palaeogeography of the northern part of Mesopotamia

Paleogeografie kvartéru severní části Mezopotámie

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Abstract: The sedimentological research described in this paper was carried out during the years 1978 and 1979. About 300 samples from shallow and deeper boreholes drilled into the sediments of the Adhaim, Diyala, Tigris, and Euphrates rivers, the Zagros Foothill zone, and the Mahmudia Formation were analysed. The analysis of heavy minerals was found to be the most functional method for distinguishing and interpreting the provenance, origin, and age of these sediments. Furthermore, the degree of corrosion of pyroxene and amphibole grains was studied in the interest of defining criteria for relative age determination. The area covered by the sediments of the Tigris, Euphrates, and Diyala rivers experienced complicated development accompanied by considerable hydrographical changes. In deep boreholes (DBH) Nos. 4 and 5, three units of the Tigris River sediments were distinguished: the "young" Tigris (Holocene to Upper Pleistocene), the "older" Tigris (Middle Pleistocene), and the "oldest" Tigris, all of which differ in the degree of corrosion of their pyroxenes and amphiboles. During the Pleistocene, the Diyala River deposited its sediments to the east of its current course. The author supposes that all rivers in the northern part of Mesopotamia migrated west and south-west during the Pleistocene and Holocene. This was probably caused by the uplift of the Zagros Mountains.

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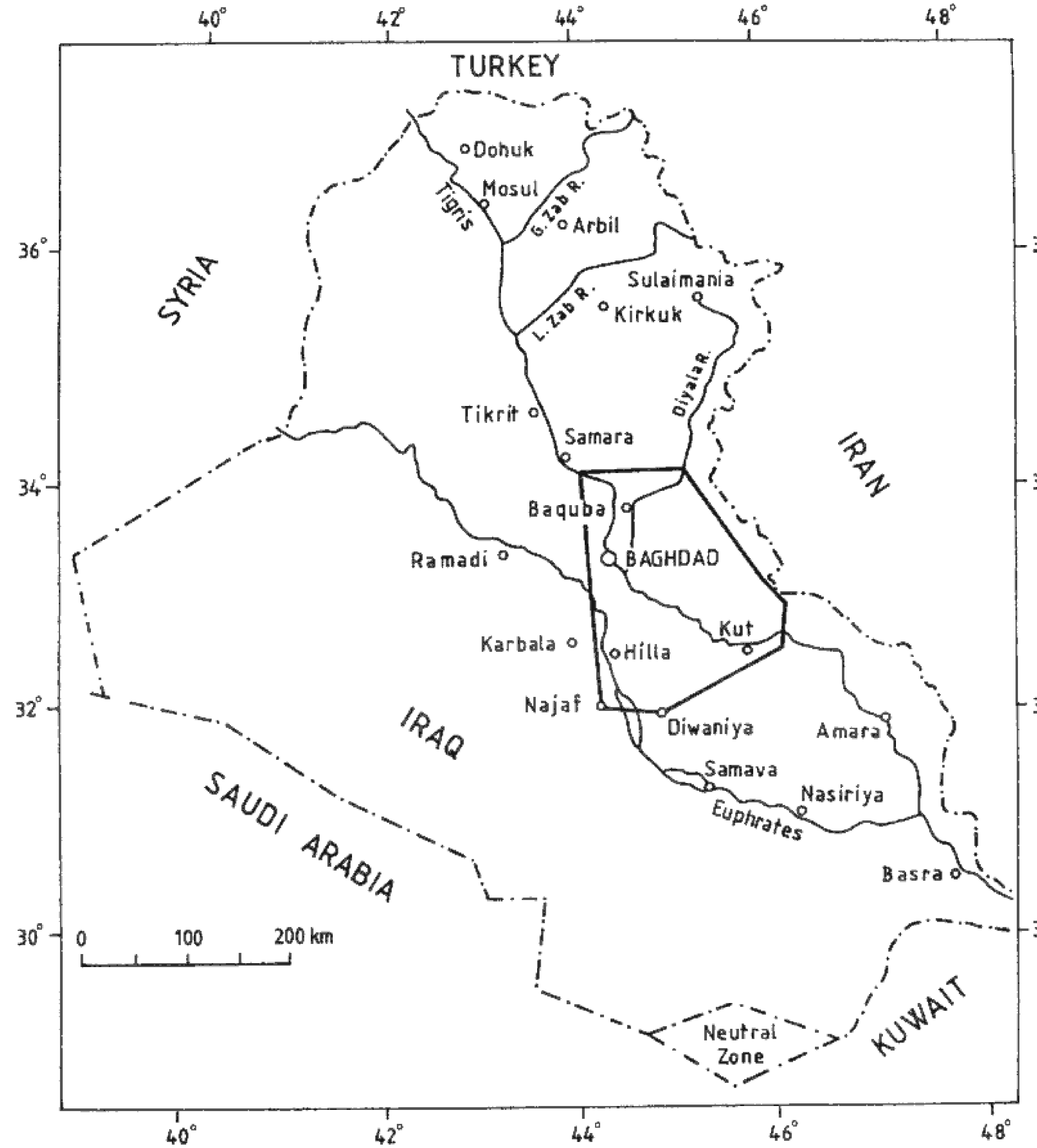
Introduction

Geological mapping was undertaken during the years 1977 and 1978 in the northern part of the Mesopotamian Plain by the State Organization for Minerals (SOM) in Baghdad. The extent of the area is shown in Figure 1. More than 100 shallow and deeper boreholes were drilled in this area. With few exceptions, the majority of the boreholes were situated on profile lines (see Figure 2).

The sedimentological research was carried out in 1978 and 1979, during which we performed grain-size analysis, and examined the petrology of the sand, gravel, and heavy mineral fractions. The composition of the heavy fraction (about 300 samples) distinguishes the sediments of different provenances. The most important clastic constituents for distinguishing the sediments of the Mesopotamian Plain were found to be the altered minerals, rock fragments, common and brownish amphibole, monoclinic pyroxene (particularly titanaugite), garnet, and, in some cases, opaque minerals. Furthermore, the degree of corrosion of the pyroxene and amphibole grains was studied. Due to significant differences in the degree of corrosion of these minerals, we were able to define certain criteria for differentiating the Upper Pleistocene, older Quaternary, and pre-Quaternary deposits.

Several authors, especially PHILIP (1968) and ALI (1977), have studied the heavy minerals of the northern part of Mesopotamia. Both of the above-mentioned authors investigated HMs particularly in the recent sediments of the Mesopotamian rivers. More recently, DOMAS, MINAŘÍKOVÁ, and SABAH (1984) presented a "Proposal on the Introduction of the Mahmudia Formation" at the Seventh Iraqi Geological Congress in 1984. According to these studies, a distinct sequence has been recognized in some boreholes in the northern part of Mesopotamia, which differs in heavy mineral content and degree of mineral corrosion from the deposits of the Tigris, Euphrates, and Diyala rivers. With respect to its sedimentological and stratigraphical position, the name Mahmudia Formation was recommended for this sequence. Some beds of finer deposits within this sequence are rich in microfossils, particulary Ostracods (as determined by Wijdan al Haddad, S.O.M.). The main Ostracod genera found in this formation are Candona, Cyprideis, Cypronotus, Ilyocypris, Darwinulla, and Lymnocythere.

Moreover, some Ostracod species typical of Pliocene and Quaternary deposits were recognized. For the Pliocene, these include *Candona* cf. *balatonica* (DADAY), *Darwinulla dadayi* NEMES, *Candona* cf. *elegans* NEMES; while the Quaternary species include *Candona* cf. *neglecta* SARS, *Candona* cf. *sucki* HARTWIG, *Candona* cf. *angulata* MÜLLER. It can be concluded from this list that the Tertiary/Quaternary boundary lies within the Mahmudia Formation. The sediments of the Mahmudia Formation were deposited mainly by rivers, and partly in lakes whose salinity oscillated from fresh to brackish. The differences in the heavy mineral content within the

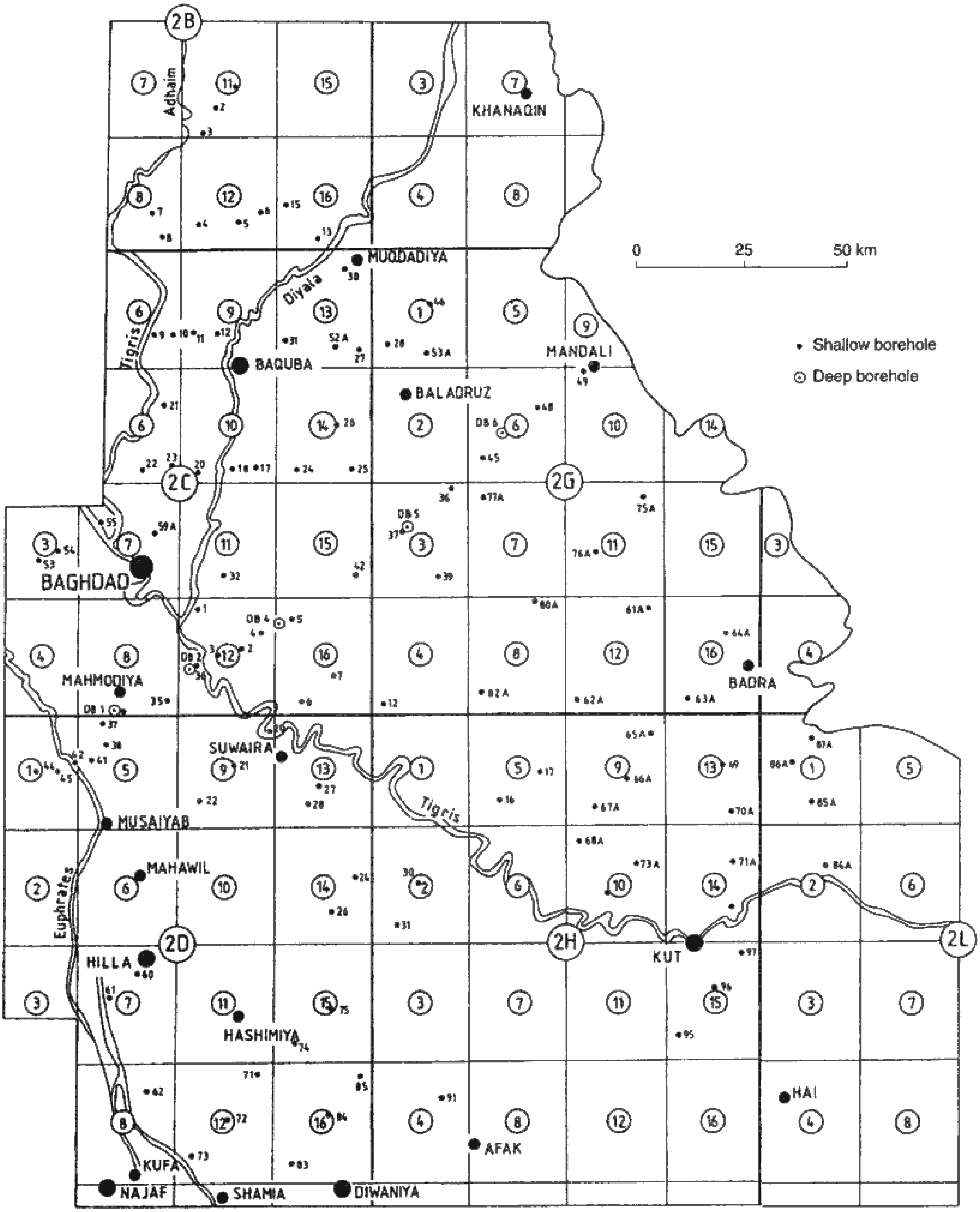


1. Map of the study area.

formation reveal that the influx of desert material was typical for the western part, whereas the clastic material to the the eastern part was supplied from the Zagros and younger uplifted structures. The clastic material of the central part was introduced by rivers from more remote areas. The proposed Mahmudia Formation overlies the Pliocene fluvial sediments and underlies the Pleistocene sediments of the Euphrates and Tigris rivers. Its deposition began in an arid Pliocene climate and ended during the first pluvial oscillations of the Pleistocene. Boundaries with the underlying and overlying beds are conformable, and are marked by the specific composition of the heavy mineral fraction and by the profound corrosion of pyroxenes, amphiboles, and garnets.

Heavy minerals (HM)

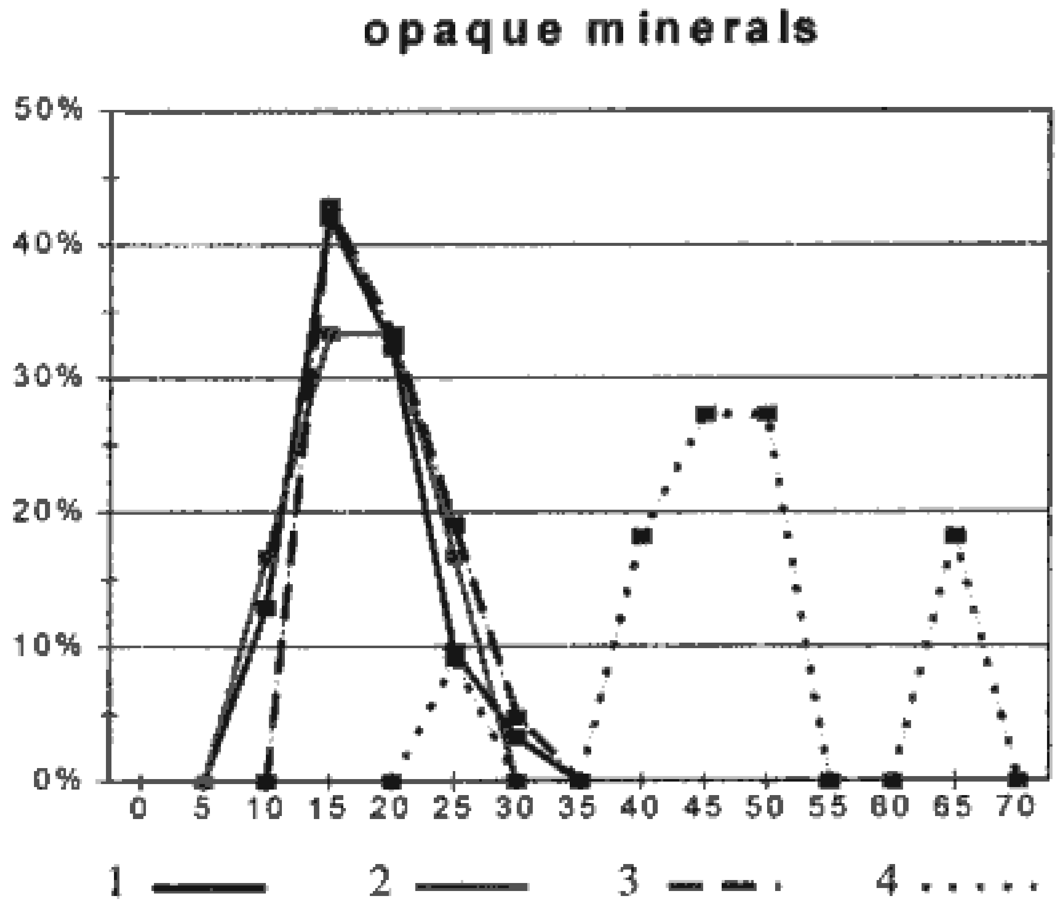
For separating the heavy mineral fraction, bromoform and magnetic separation techniques were used. The quantitative composition of the heavy fraction was determined by the study of samples mounted in Canadian Balsam. The total content of the heavy fraction (in weight %) was found to be important for distinguishing



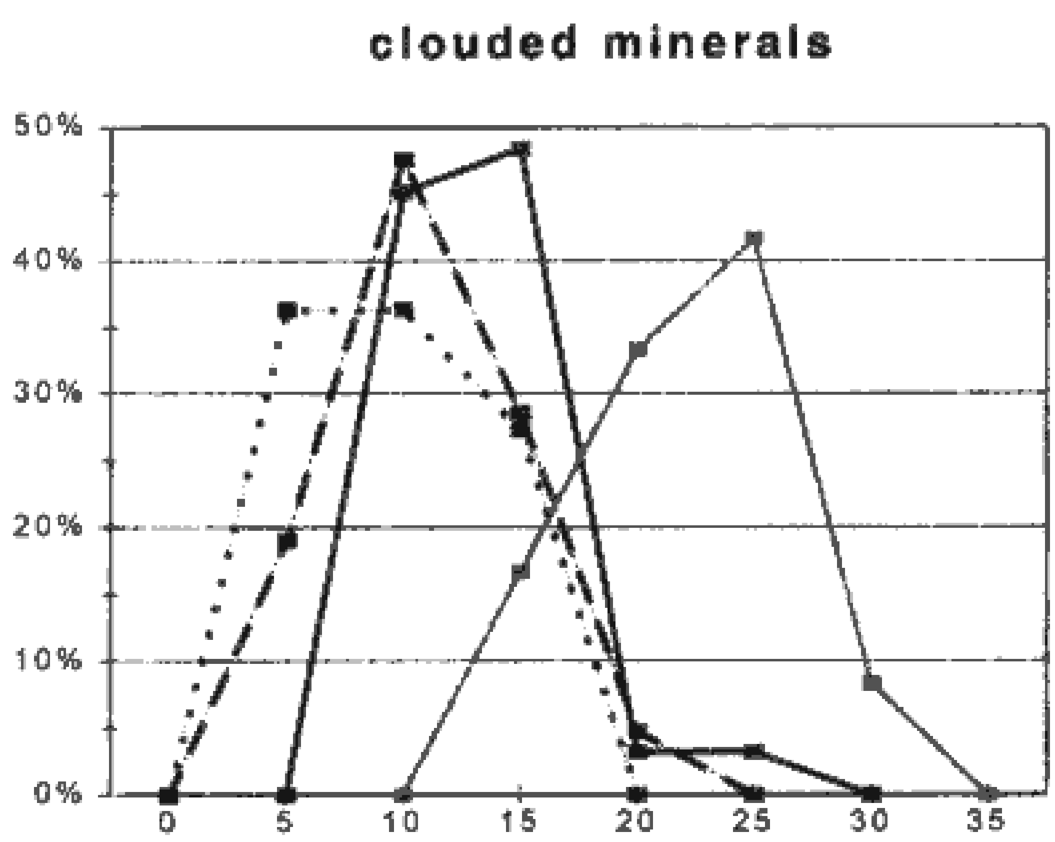
2. Location of boreholes according to coordinates.

between the sediments of the Diyala and Tigris rivers. Low heavy mineral contents were observed in the Zagros foothill sediments and in the Diyala and Adhaim river deposits. The results of these analyses are presented in Tables 1–8 on pages 22–30 (in Tables 1–7 are shallow boreholes – SBH, and in Table 8 is a deeper borehole – DBH; MINAŘÍKOVÁ 1978, 1979).

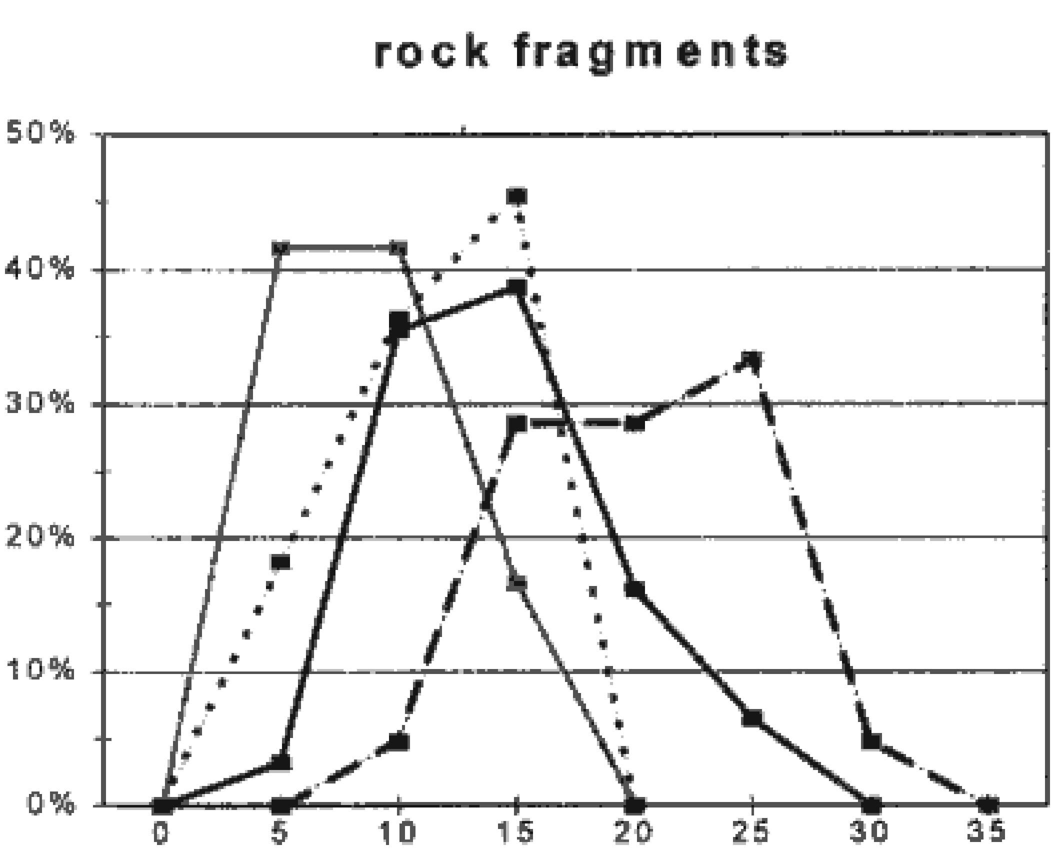
The magnetic fraction is comprised mainly of magnetite, with rare pyrrhotine and titanomagnetite. Relatively higher magnetic fraction contents were found in



3. Relative frequency of opaque minerals. 1 – Tigris River deposits; 2 – Euphrates River deposits; 3 – Diyala River deposits; 4 – Foothill zone deposits.



4. Relative frequency of clouded minerals. For explanations see Figure 3.



5. Relative frequency of rock fragments. For explanations see Figure 3.

the Diyala River sediments and the foothill deposits. Opaque minerals are represented mainly by limonite and ilmenite. Limonite usually predominates over ilmenite, while the opposite relation is rather exceptional. In many samples some of the ilmenite grains are covered with leucoxene and limonite. Hematite and pyrite are rare. Opaque minerals are abundant, especially in the foothill sediments, but most of them are authigenic. Figure 3 shows the distribution of opaque minerals in the sediments of the Tigris, Euphrates, and Diyala rivers and the foothill zone.

All minerals that were not amenable to reliable determination are included under clouded minerals. They seem to be strongly weathered minerals of the zoisite-epidote group, with a minor proportion of amphiboles. Their content is important for distinguishing between the sediments of the Tigris and Euphrates rivers (see Figure 4).

Most of the rock fragments found in the heavy fraction contain minerals of the zoisite-epidote group, green schist, amphibolite, and basic igneous rocks. They are usually altered and weathered. Such rock fragments are present mainly in sediments of the Adhaim and the Diyala, less in the Tigris and Foothill zone deposits. The Euphrates River sediments contain a smaller proportion of rock fragments (see Figure 5).

Minerals of the zoisite-epidote group include epidote, clinozoisite, and zoisite; piemontite is rare. They are often partly altered. These minerals are plentiful in the Adhaim River sediments (see Table 1), but occur less frequently in deposits of the other rivers and the Foothill zone (see Figure 6).

Common amphibole includes several varieties that differ in colour and intensity of pleochroism. A greyish-green variety with mild pleochroism is the most common. Varieties of an intense green colour are rare. Amphibole is more abundant in the Tigris sediments than in those of Euphrates and Diyala (see Figure 7), and is rare in the Adhaim and Foothill deposits (see Tables 1–8). The brownish amphibole is mostly basaltic amphibole, but sometimes common amphibole. Tremolite-actinolite is not rare but it is a minor accessory mineral.

Orthopyroxenes include an isomorphous series of enstatite, bronzite, and hypersthene. Their total content is low, but they show significant differences among the different provinces. The highest proportion of orthopyroxenes was found in the Diyala deposits, and somewhat less in the Tigris and Euphrates deposits. The foothill sediments, and especially the Adhaim River sediments, contain a very minor orthopyroxene fraction (see Tables 1–8). Monoclinic pyroxenes found in these sediments include nonpleochroic, light green diopside augite, and smaller proportions of a greener, pleochroic augite. Titanaugite was found particularly in the Diyala River deposits, while in the Tigris and Euphrates sediments it is a common but minor mineral. The Foothill zone and Adhaim River deposits contain very minor fractions of this mineral(see Tables 1–8). Titanaugite is typically brown-violet and pleochroic. The relative frequency diagram in Figure 8 shows the distribution of augite and titanaugite together. Whitish pyroxenes present in these sediments are grains of diopside.

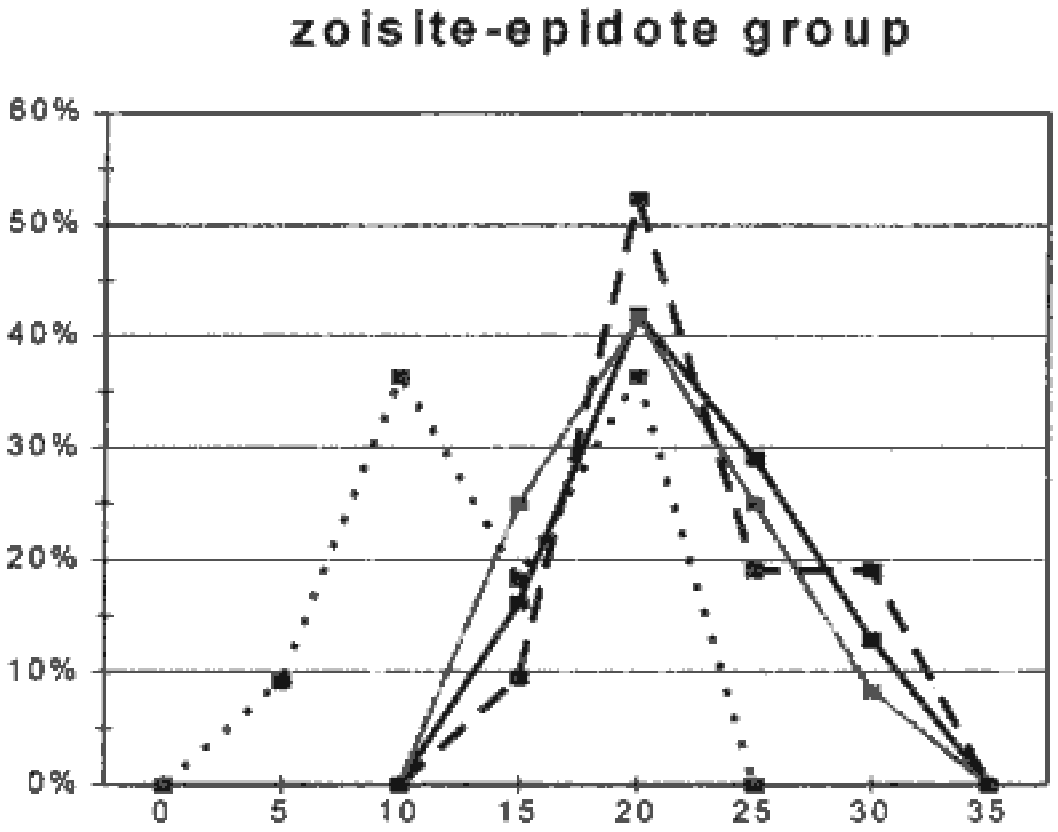
The garnet found in these sediments is commonly light pink, sometimes colourless, rarely yellow or brown. Most of the grains have irregular shapes, but some idiomorphic crystals do occur. The relative frequency of garnet in the studied sediments is shown in Figure 9.

Rare minerals include rutile, zircon, tourmaline, titanite, andalusite, sillimanite, kyanite, staurolite, and chromite. Titanite, chromite, and tourmaline were found mainly in the Diyala River sediments. The Tigris River deposits contain the same rare minerals, with the addition of chromite. The Euphrates River sediments have a slightly higher content of metamorphic minerals than those of the Tigris. The Foothill zone and the Adhaim River deposits contain more rutile, zircon, and chromite, and less sillimanite and staurolite (see Tables 1–8).

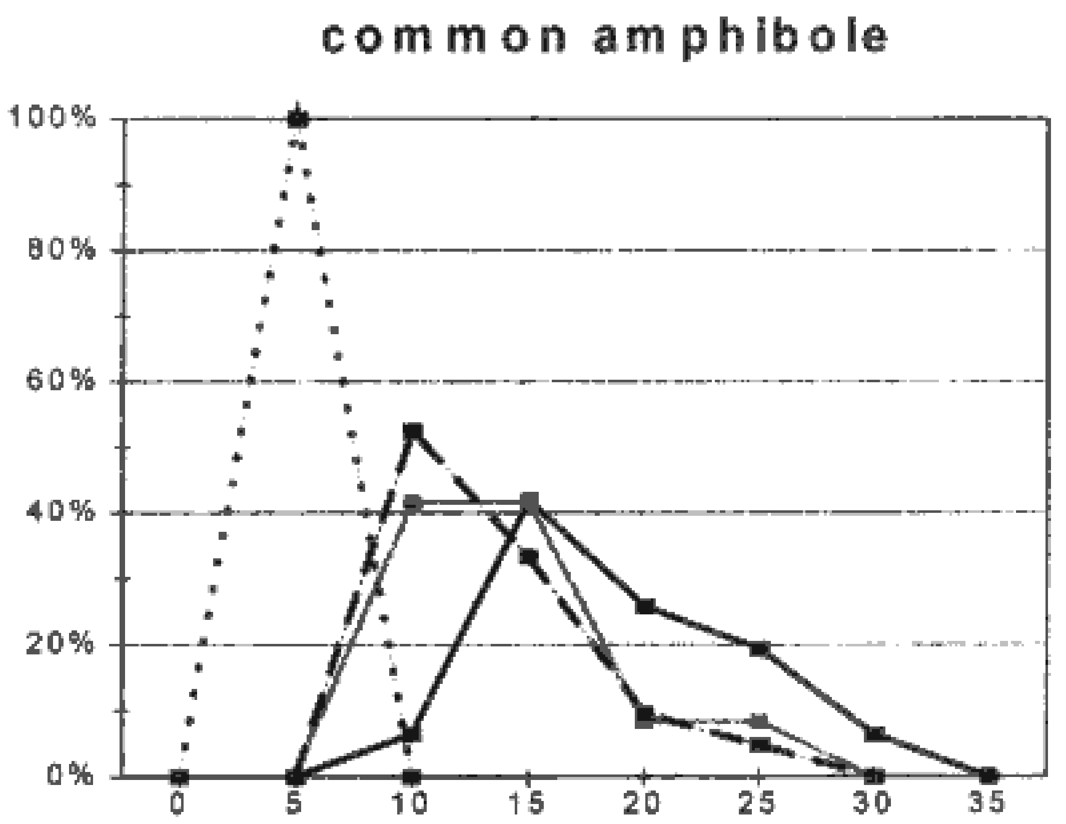
The mica minerals of these sediments are mainly chlorite, with less biotite. The quantity of chlorite was found to depend on grain-size distribution, as it is more common in very fine-grained deposits. Minerals of the barite-celestite isomorphous mixture are of authigenic origin, and were found particularly in the Foothill and the Adhaim River sediments, in which they are relatively common (see Tables 1–8). Very rare minerals in these sediments include spinel, monazite, xenotime, corundum, and topaz.

From this review it is clear that the quantity of clouded minerals, rock fragments, common amphibole, monoclinic pyroxenes (including titanaugite) and garnet are very important for distinguishing the sediments of different rivers and formations. To illustrate these differences, a triangle diagram representing clouded minerals, rock fragments, and common amphibole has been constructed (see Figure 10). This diagram shows the relatively poor separation of the fields of the Tigris and Euphrates rivers sediments in contrast to the distinct fields of the Diyala River and Foothill deposits.

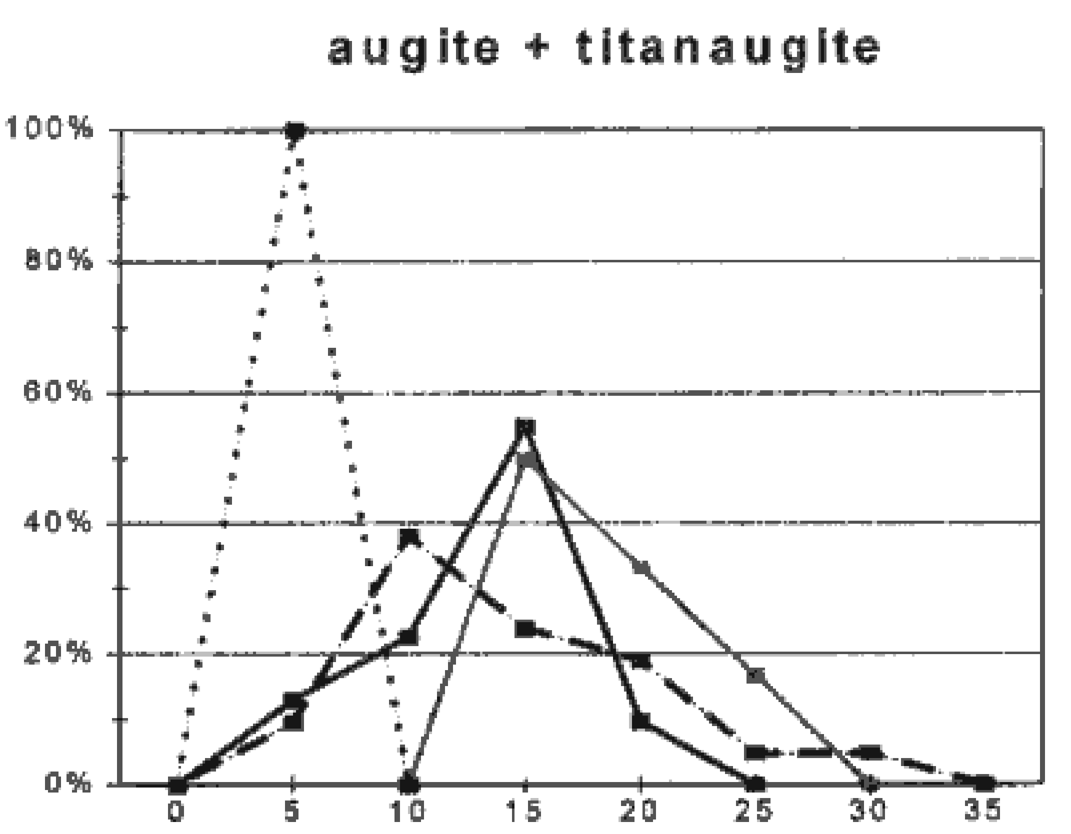
In addition, the degree of corrosion of mineral grains was used for distinguishing sediments of different ages. Corrosion is apparent mainly in pyroxenes, less in amphiboles and garnet. In the Holocene and Upper Pleistocene sediments, only the pyroxene grains are weakly corroded. Stronger pyroxene corrosion, and partial corrosion of amphiboles, was found in the Middle Pleistocene deposits of the Diyala and Tigris rivers. Pyroxenes are strongly corroded in the sediments of the Mahmudia Formation, in which corrosion features on amphibole (common and brownish) and garnet grains is also clearly seen. Mineral corrosion was found to be more extensive in the pre-Quaternary sediments.

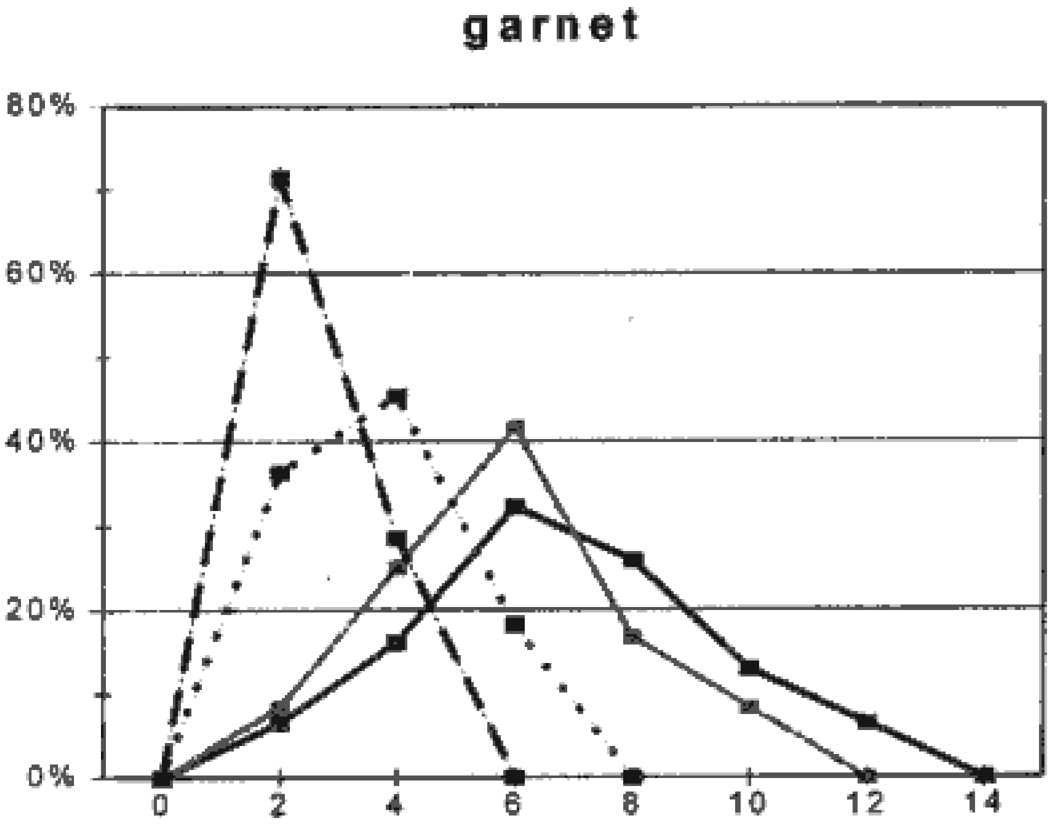


6. Relative frequency of minerals of zoisite-epidote group. For explanations see Figure 3.

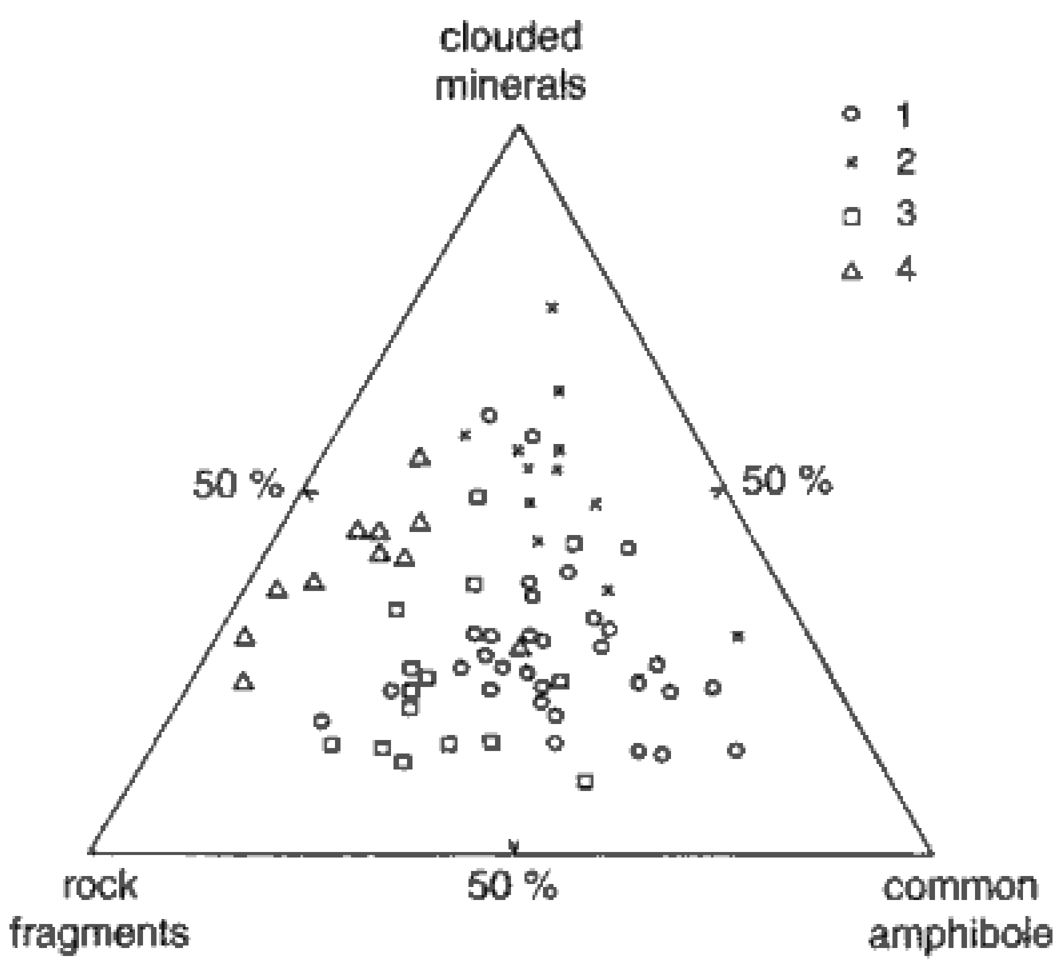


7. Relative frequency of common amphibole. For explantions see Figure 3.





9. Relative frequency of garnet. For explanations see Figure 3.



10. Triangle diagram showing the contents of clouded minerals, rock fragments and common amphibole. 1 – Tigris River deposits; 2 – Euphrates River deposits; 3 – Diyala River deposits; 4 – Foothill zone deposits.

Description of the sediments from the deeper boreholes (DBH)

In the year 1978, five deeper boreholes were drilled into the Mesopotamian Plain. These boreholes were arranged in a SW-NE trending profile between Mahmudia and Mandali (see Figure 2). The main goals of investigating the DBH sediments were:

1. to locate a boundary between Quaternary and pre-Quaternary deposits;
2. to distinguish between the sediments of individual rivers; and,
3. to determine relative age of the Quaternary deposits.

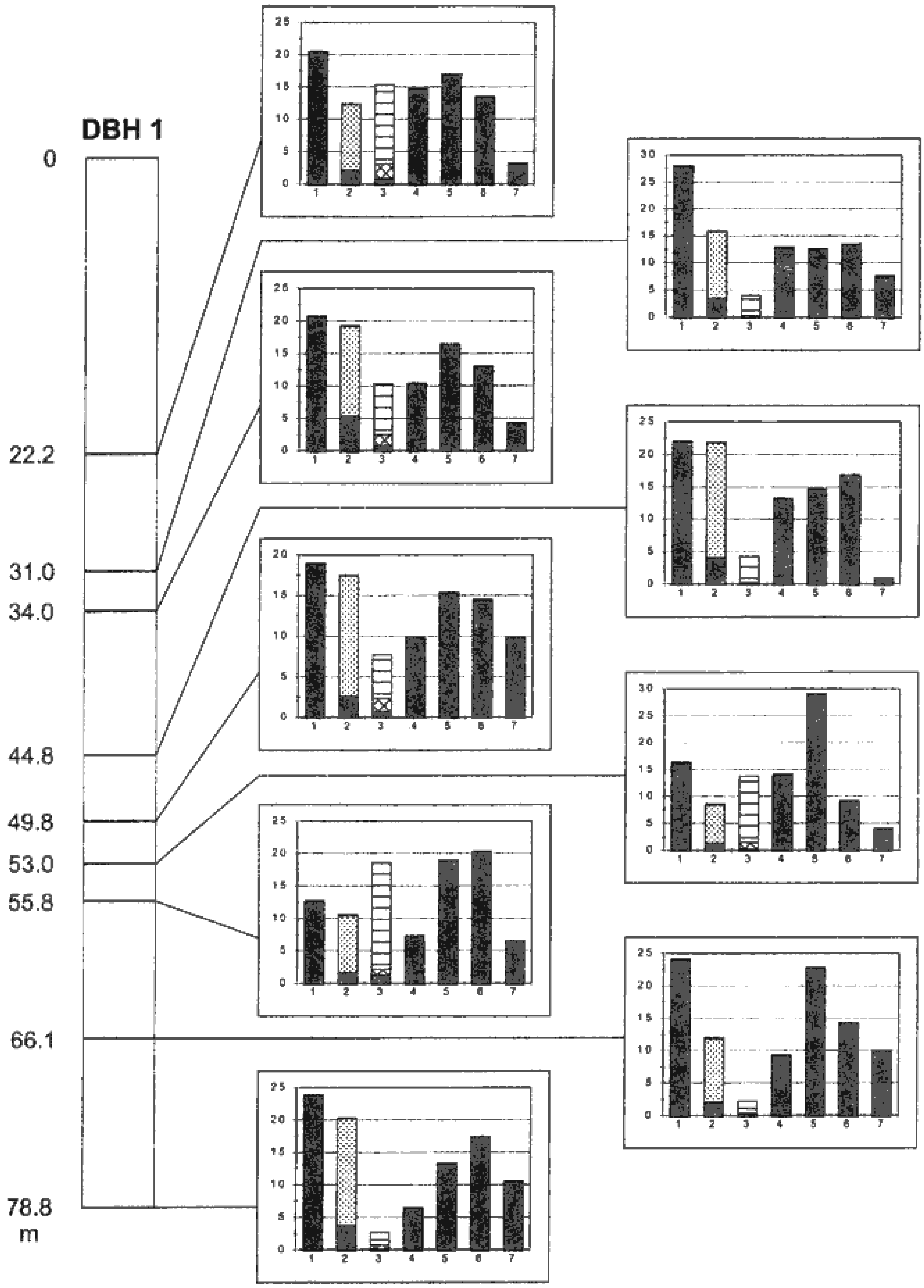
DBH 1 was situated due south of Mahmudia (see Figure 2). The HM composition of these sediments is shown in Table 8 and Figure 11.

Sample No. 1 (22.05–22.20 m) is a fine-grained sand, relatively well sorted and containing only about 5 % of silt and clay particles. Quartz predominates in the < 0.354 mm fraction; rock fragments comprise about 20 %. The coarser fractions are comprised mainly of rock fragments, mostly of chert, with smaller proportions of sandstone, siltstone, carbonates and quartzite. The quartz grains range from being rounded to well rounded in the > 0.5 mm fraction, whereas they are subangular and subrounded in finer fractions. The HM composition shows that the sand is a mixture of Tigris and Euphrates deposits. Sample No. 2 (30.9–31.0 m) contains a significant admixture of silt and clay particles. The composition and degree of roundness of its sandy fraction is similar to that of sample No. 1. The HM fraction of sample No. 2 has a very low pyroxene content, and is of a similar composition to that of the Mahmudia Formation deposits. The author supposes that sample No. 2 represents redeposited sediments of the Mahmudia Formation. In sample No. 3 (33.95–34.05 m) the > 0.354 mm fraction contains mostly mica minerals. Finer fractions are composed of quartz and rock fragments, with minor feldspar. The composition of the heavy mineral fraction shows that it is mixture of the Tigris and Euphrates River deposits. Sample No. 4 is a mixture of sand, silt, and clay, with a small admixture of pebbles, and contains the same rock types as in the overlying beds. It can be concluded that sample No. 4 also represents redeposited sediment from the Mahmudia Formation. The HM composition of sample No. 5 (49.6–49.8 m) indicates that it is a mixture of the Tigris and Euphrates deposits. The heavy mineral fraction of sample No. 6 (52.8–53.0 m) is characterized by a high content of clouded minerals, indicative of the Euphrates River provenance. The heavy mineral fraction of sample No. 7 (55.7–55.8 m) shows that this sediment was deposited by the Euphrates River. However, there are significant differences in the degree of corrosion of some minerals in comparison with those in the overlying beds. The pyroxene grains of sample No. 7 are more strongly corroded, while corrosion textures are also present on amphibole grains. Based on the relative degree of corrosion, it is suggested that these sediments represent an "older Euphrates".

Samples No. 8 (65.9–66.1 m) and No. 52 (78.75–78.85 m) have the same composition as the sediments of the Mahmudia Formation in this area. Their HMs are weathered, their amphibole and garnet are corroded, and their pyroxene is strongly corroded. All of these features place these sediments in the Mahmudia Formation.

Samples 1–6 correspond to Upper Pleistocene, while sample No. 7 could be of Middle Pleistocene age.

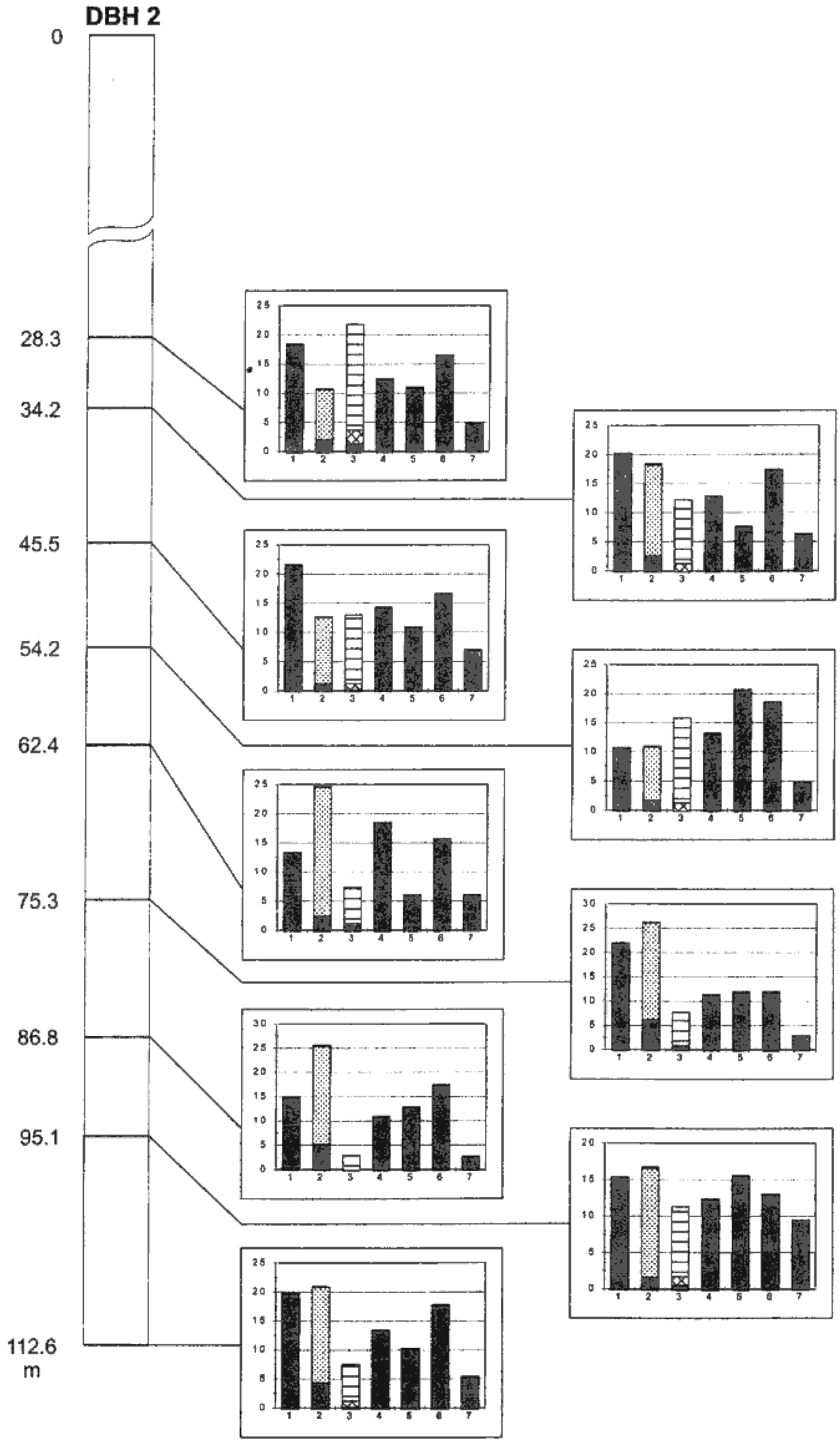
DBH 2 was situated on the right bank of the Tigris River (see Figure 2). Its heavy fraction composition is shown in Table 8, for histograms of the main minerals see Figure 12. The upper part of the sequence is comprised of Tigris River sediments, with local admixtures of Euphrates River deposits (sample No. 6 – 28.1–28.3 m). Euphra-



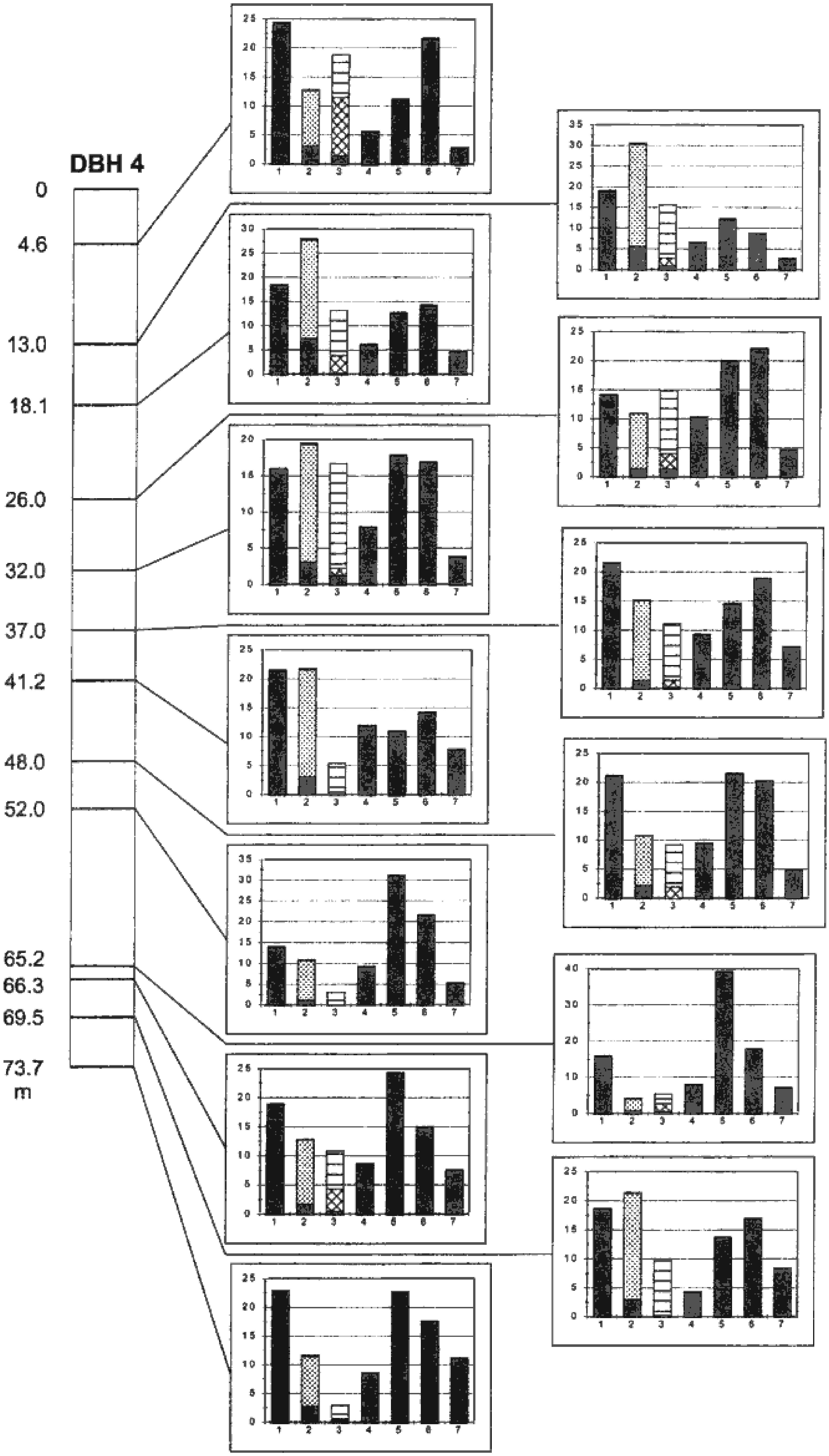
11. Histograms of the main HM in sediments of DBH No. 1. 1 – minerals of the zoisite-epidote group; 2 – amphibole group (lower part of the column – brownish amphibole, upper part – common amphibole); 3 – pyroxene group (lower part – orthopyroxene, middle part – titanaugite, upper part – augite and diopside augite); 4 – rock fragments; 5 – clouded minerals; 6 – opaque minerals; 7 – garnet.

tes River deposits were found at a depth of more than 50 m (sample No. 9), which correspond to those evinced in DBH 1 at a depth of 53 m. In the next two samples (No. 10 – 62.2–62.4 m, and No. 11 – 75.0–75.3 m) the HM composition and the degree of corrosion are similar to those of the Mahmudia Formation deposits. Corroded grains of garnet and amphibole and strongly corroded pyroxenes were found in the last three samples (Nos. 18, 32 and 49). The author supposes that these sediments are pre-Quaternary.

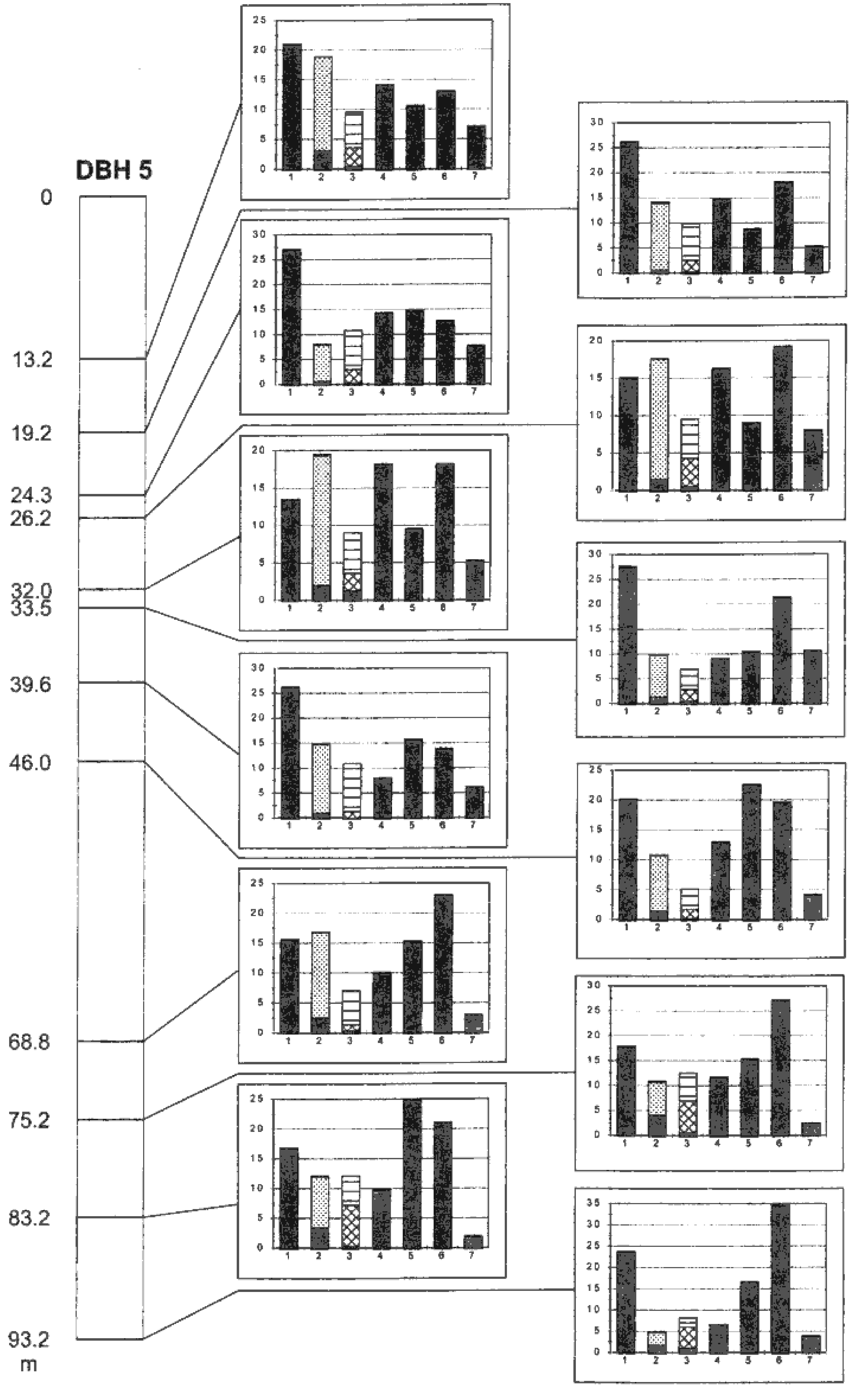
DBH 4 was situated in the NW margin of map sheet 2C16 (see Figure 2). The HM composition of this sample is shown in Table 8 and in the histograms in Figure 13. Sample No. 16 (4.5–4.6 m) represents the typical sediment of the Diyala River. Sample No. 17 (12.9–13.0 m) is a mixture of deposits from the Tigris and the Diyala



12. Histograms of the main HM in sediments of DBH No. 2. For explanations see Figure 11.



13. Histograms of the main HM in sediments of DBH No. 4. For explanations see Figure 11.



14. Histograms of the main HM in sediments of DBH No. 5. For explanations see Figure 11.

rivers. Samples 18, 19, and 20 (from a depth range of 18–32 m) have the same composition as the Tigris River sediments, although the degree of corrosion on pyroxene and amphibole grains is a little higher than in the Upper Pleistocene deposits. These sediments must therefore be older, and are thus referred to as "older" Tigris River sediments. Samples 21, 22, and 23 (from a depth range of 37–48 m) are characterized by pyroxene and amphibole with an even higher degree of corrosion. Their HM composition is similar to that of the Tigris River sediments. It is therefore concluded that these sediments were also deposited by the Tigris River. However, they are clearly older than the overlying beds at depths between 18–32 m, and thus we use the term "oldest Tigris River sediments" with reference to them. The next three samples, Nos. 24, 44, and 46 (in the depth of 52–66 m), represent sediments of the Mahmudia Formation. The last two samples, Nos. 54 and 55 (from a depth range of 69–74 m), correspond to the pre-Quaternary sediments with respect to their composition and degree of corrosion.

DBH 5 was situated near the centre of map sheet 2G3 (see Figure 2). This sample contained the same sediments as in DBH 4 (see Table 8 and Figure 14): i. e., the Upper Pleistocene „young Tigris", the „older Tigris" (at a depth of 19–32 m), and the „oldest Tigris" (at 33–46 m). The age of the last two units of this sample cannot be exactly determined due to the absence of palaeontological evidence. The lower part of the borehole, below 68 m in depth, probably passed through the Mahmudia Formation.

DBH 6 was situated SW of Mandali (see Figure 2). Its HM composition is shown in Table 8. The first three samples (Nos. 8, 9, and 69, from depths between 21.4–49.2 m) represent Zagros Foothill zone deposits. High contents of opaque minerals and low contents of amphibole and pyroxene are typical of these sediments. Authigenic minerals of the barite-celestite group are present in all samples. The HM compositions of the remaining nine samples, from depths of 56.5 to 202.4 m, are very similar to those of the foothill deposits, but their pyroxene and amphibole grains are strongly corroded. We therefore suppose that these sediments are pre-Quaternary in age.

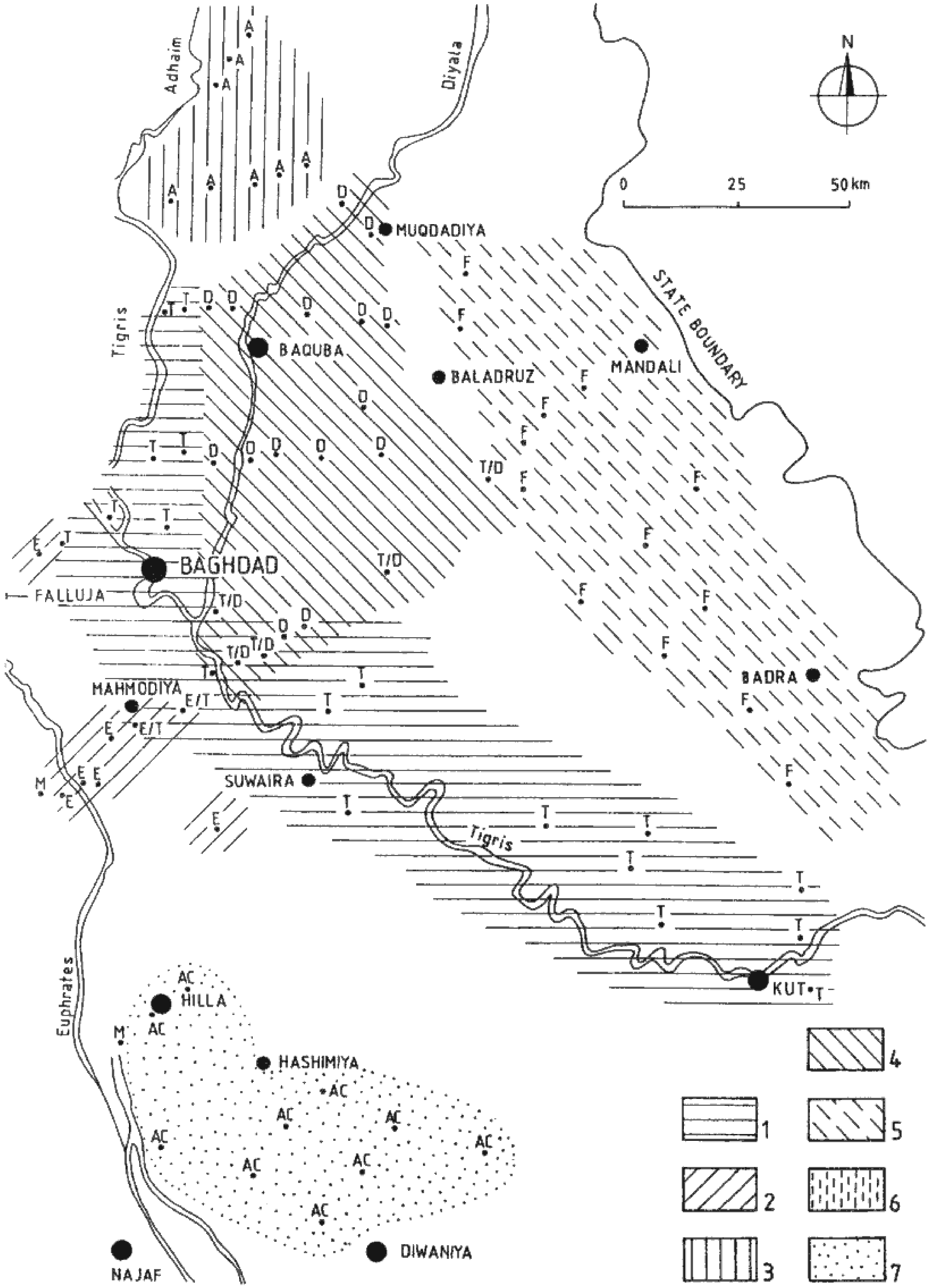
The investigation of sediments from deeper boreholes confirm that the Tigris and Euphrates rivers migrated westward during the Pleistocene and Holocene. The most intense accumulations probably occurred in successive phases during the Upper Pleistocene and the Holocene, within the area between Mahmudia and Salman Pak (DBH Nos. 1 and 2). This massive accumulation could have been caused by subsidence, or by intense denudation in the source areas. The presence of older Tigris River sediments at the same depth and not very far to the east (in the DBH Nos. 4 and 5), supports the latter possibility.

Characteristics and extent of the sediments

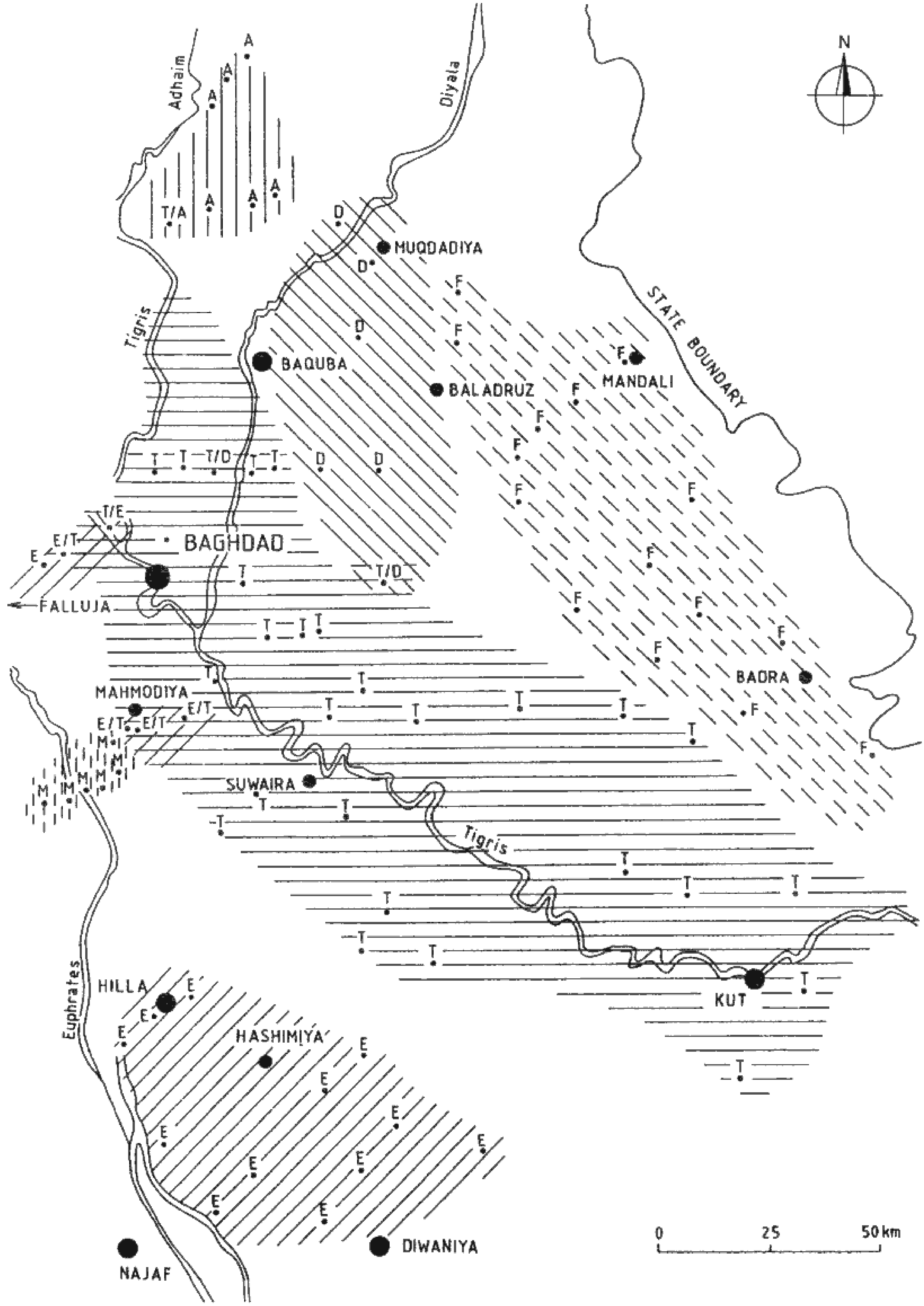
The sediments of the Adhaim River were studied by means of shallow boreholes (SBH) along the river's left bank (see Figure 15). These sediments are characterized by a very high content of minerals from the zoisite-epidote group, relatively high rock fragment contents, very low amphibole contents, and an extremely low pyroxene contents (see Table 1). The composition is vertically and horizontally constant, which confirms that the source of the clastic material must be sought for in the older sedimentary formations to the north.

The young (probably Holocene) Diyala River sediments border this river's present course up to its confluence with the Tigris River. To the S and SE they are often enriched with material from the Tigris River, reseposited from underlying beds (see Figure 15). Rock fragments prevail over clouded minerals in these sediments. The quantities of minerals from the zoisite-epidote, amphibole, and pyroxene groups are similar to those of the Tigris and the Euphrates sediments; the Diyala deposits, however, contain more orthopyroxene and significantly more titanaugite. The garnet content is very low. Metamorphic minerals are almost completely absent (see Tables 1, 2, and 4). The Upper Pleistocene deposits of the Diyala seem to occur only on the left bank (southward of Baquba) of the present Diyala River (see Figure 16). Older Diyala River sediments were found below the depth of 12–14 m. They differ from the younger deposits by being significantly higher in titanaugite, and by higher degrees of pyroxene and amphibole corrosion. These sediments occur on the left bank of the Diyala River to the south of Muqdadiya (see Figure 17), and are possibly of Middle Pleistocene age. The HM fraction of the Diyala River deposits indicate that the source of the clastics is to be sought in the basic igneous rocks of the Walash Series, along the border between Iraq and Iran.

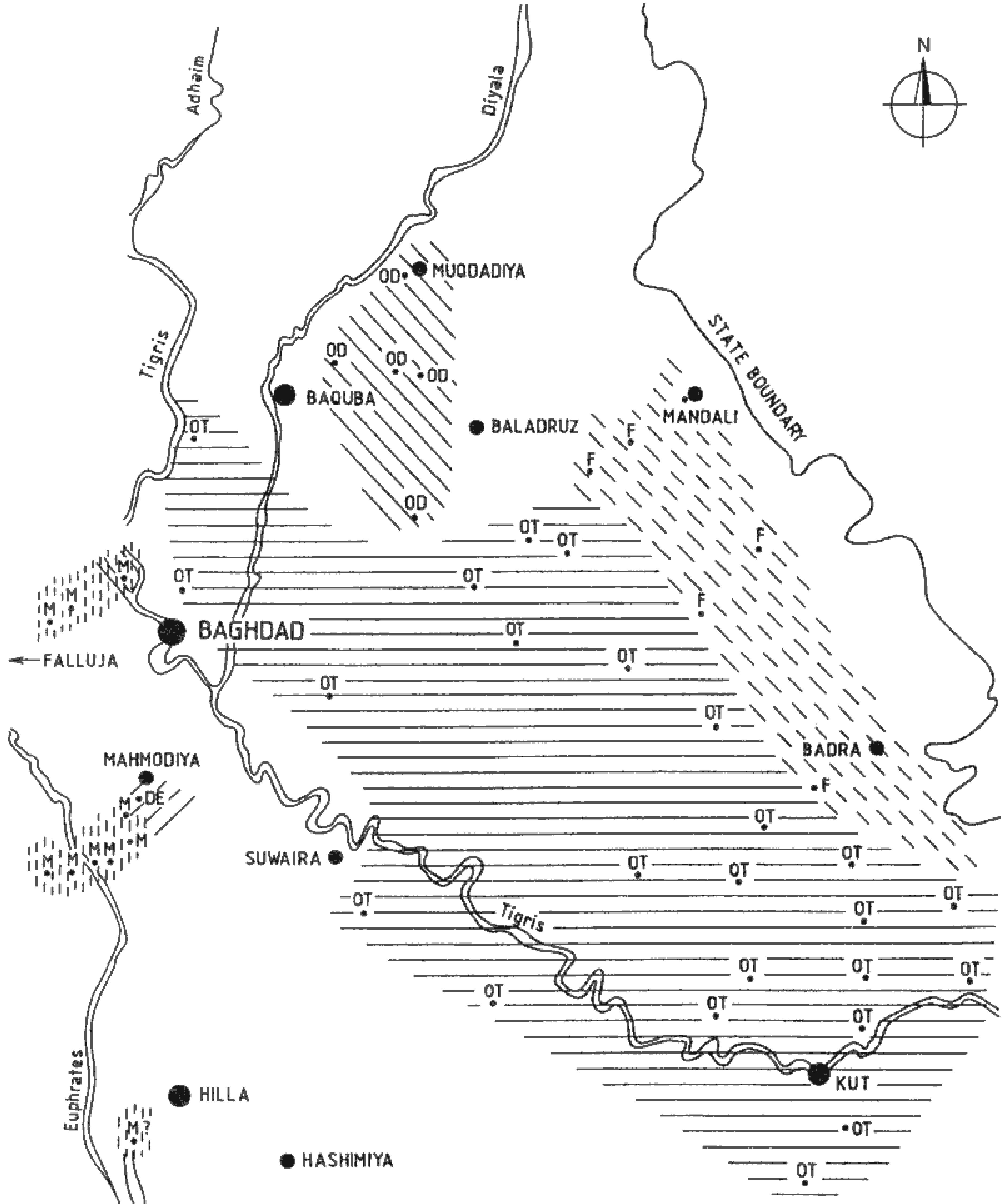
The Holocene sediments of the Tigris River border its present course. To the north of Baghdad the boundary between the sediments of the Tigris and Diyala rivers is sharp; while the mixing of their deposits appears in the vicinity of their confluence (see Figure 15). The Tigris River sediments that constitute a wide belt reaching many kilometres to the east of the river's present course (see Figure 16) are probably of Upper Pleistocene age. In the western part, they are covered by Holocene sediments from the Diyala River (compare Figures 15 and 16). The medium content of clouded minerals and rock fragments, and the presence of titanaugite downstream from the mouth of the Diyala River, are typical characteristics of the HM fraction. The Tigris River deposits contain much more garnet than those of the Diyala River (see Tables 2–8). Sediments that must be older than Upper Pleistocene were found in DBHs Nos. 4 and 5, and in several SBHs in the NE margin of the Plain (between Baladruz and Kut; see Figure 17). The composition of their heavy fraction does not differ significantly, though



15. Extent of the Tigris, Euphrates, Adhaim, Diyala, and Foothill zone sediments, and the Mahmudia Formation. 1 – Tigris River deposits; 2 – Euphrates River deposits; 3 – Adhaim River deposits; 4 – Diyala River deposits; 5 – Foothill zone deposits; 6 – Mahmudia Formation; 7 – deposits from artificial canals.



16. Extent of the Upper Pleistocene deposits. For explanations see Figure 15.



17. Extent of the Middle Pleistocene deposits. For explanations see Figure 15.

amphibole grains are corroded and the pyroxene corrosion a little stronger than in the Upper Pleistocene deposits. These sediments lie below a depth of 18 m, and are about 15 m in thickness. Unfortunately, there is no paleontological evidence for determining their age. They appear to be of Middle Pleistocene age, and thus the term "older" Tigris River sediments is used for them. Another older unit of the Tigris River deposits was found in the same DBHs (Nos. 4 and 5). This unit occupies a depth range from 33 m to about 50 m, and contains less pyroxene, though the quantity of other heavy minerals is similar (see Table 8). The corrosion of pyroxene and amphibole grains is evidently stronger than in the Upper Pleistocene and the "older Tigris" sediments. The "oldest Tigris River sediments" is the provisional term for this unit.

The Holocene sediments of the Euphrates River border its present course (see Figure 15). This river's older sediments have been located in the area between the present courses of the Euphrates and Tigris rivers (see Figure 16). The HM assemblage of the Euphrates deposits is very similar to that of the Tigris River sediments. Significant differences were found only in the contents of pyroxene, clouded minerals, and rock fragments. The Euphrates River sediments contain a slightly larger amount of metamorphic minerals (see Tables 1–8). The surface of the area between Hilla and Diwaniya is covered by recent deposits from artificial canals (see Figure 15). The composition of their heavy fraction differs from the typical Euphrates River sediments in that the former contain great amount of amphibole and very minor garnet. Chlorite and biotite are commonly present (see Tables 5 and 7). These canal deposits are usually fine-grained. It is supposed that the differences in HM content are mostly caused by the differences in grain-size distribution. In DBH No. 1 and SBH Nos. 53, 54, 34, and 35 (see Figure 2) the mixed sediments of the Euphrates and Tigris rivers are present to a depth of about 50 m. These deposits do not show a higher degree of amphibole and pyroxene corrosion, and must therefore be young, probably of Upper Pleistocene age. The oldest sediments of the Euphrates River were hitherto found close to Mahmudia in DBH No. 1, at a depth of more than 50 m. Considering the corrosion of amphibole and pyroxene, these deposits seem to correspond to sediments of the "older Tigris," and could therefore be of Middle Pleistocene age.

The NE part of the Mesopotamian Plain is covered by large alluvial fans preserved in the foothill zone of the Zagros Mountains. The HM contents of these sediments consist mainly of opaque minerals (partly of authigenic origin), minerals of the zoisite-epidote group, and authigenic minerals of the barite-celestite group (see Tables 1, 5, 6, and 8). This HM composition indicates that the Zagros Foothill zone deposits were derived from the neighbouring mountains, which were built-up from the Bakhtiari and Fars sedimentary formations. In the area between Mandali and Badra, the Foothill zone deposits overlap sediments of the "older Tigris" (compare Figures 16 and 17).

The sediments of the Mahmudia Formation (Domas et al. 1984) in the western part of the study area were investigated in shallow and deeper boreholes (see and compare Figures 15, 16, and 17). The HM content of these sediments differs from those of the Euphrates and Tigris by having a higher brownish amphibole content and a lower pyroxene content (see Tables 2, 3, and 8). Grains of pyroxene, amphibole, and garnet show strong corrosion. There was a marked change in the paleoclimate during the deposition of the Mahmudia Formation, which began in an arid Pliocene climate and ended during the first (oldest) pluvial oscillations of the Pleistocene.

Palaeogeographical conclusions

The N and NE parts of the territory under consideration are covered by sediments from the Adhaim River and by Zagros Foothill zone deposits. It seems that no substantial changes took place in this area during the Upper Pleistocene and Holocene. Only in the area between Mandali and Badra, where the foothill deposits overlie the sediments of the "older" Tigris. These covering sediments reach far to the west during this period of time (compare Figures 17 and 15, 16).

The remaining part of the area, covered by sediments from the Tigris, Euphrates, and Diyala rivers, experienced complex development accompanied by substantial hydrographical changes.

The Tigris River deposited its sediments more than 100 km to the east of its present course during the Upper, Middle, and perhaps even the Lower Pleistocene. At that time, the Tigris River sediments extended as far as the NE part of the Mesopotamian Plain, where they came into contact with Foothill zone deposits. To the north of Baghdad, the course of the Tigris River turned to the east, toward Baquba, to the area of the contemporary course of the Diyala River (compare Figures 15 and 16). During Upper Pleistocene, the Tigris River gradually shifted its course increasingly to the W and SW. During the Holocene, the Tigris River accumulated sediments along its present course (see Figure 15).

Pleistocene accumulations of the Diyala River were deposited to the E of its present course. During the Holocene, or perhaps even towards the end of the Upper Pleistocene, when the Tigris River migrated westward, the course of the Diyala River must have undergone large scale changes. The whole NE part of the Mesopotamian Plain is built up by sediments of the Diyala River, which overlie Upper Pleistocene and older sediments of the Tigris River. The confluence of the Diyala with the Tigris River shifted downstream from the Baquba area toward Baghdad, and the course of the Diyala River gradually migrated to the W(compare Figures 15 and 16).

The older sediments of the Euphrates River, possibly of Middle Pleistocene age, and its Upper Pleistocene equivalents, also occur eastward of its present course. During the Upper Pleistocene, mixing of the Euphrates and Tigris rivers sediments took place in the Falluja and Mahmudia areas. The Euphrates River seems to have migrated westward by the end of Upper Pleistocene and during the Holocene. SW of Mahmudia, for example, the Holocene sediments of the Euphrates River rest immediately upon the Mahmudia Formation (compare Figures 15, 16, and 17).

The courses of all rivers in the N part of the Mesopotamian Plain migrated due W and SW during the Pleistocene and Holocene. Among the controlling factors of this migration, tectonics and climate changes were of major importance. The author concludes that the main cause was the gradual uplift of the Zagros Mountains. The progress of the Foothill zone sediments into the Mesopotamian Plain during the Upper Pleistocene and Holocene further supports this view.

The most intense accumulation from what seems to be a younger phase of the Upper Pleistocene and Holocene occurs in the area between Mahmudia and Salman Pak, where younger sediments of great thickness occur. This massive accumulation could have been controlled either by subsidence or by strong erosion and denudation at the source area. The presence of older sediments from the Tigris River at the same depth, and not far to the E (in DBH Nos. 4 and 5), favours the second possibility.

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References

ALI, J. A. (1977): Heavy mineral provinces of the recent sediments of the Euphrates-Tigris basin. – J. Geol. Soc. Iraq, 10., 33–46. Baghdad.

DOMAS, J. – MINAŘÍKOVÁ, D. – SABAH, Y. Y. (1984): Proposal on the introduction of the Mahmudia Formation. – Lecture on the 7th Iraqi Geological Congress in Baghdad. Baghdad.

MINAŘÍKOVÁ, D. (1978): Preliminary study of the heavy minerals of the Quaternary sediments and Upper Fars Formation in northern part of Mesopotamia. Sketch of paleogeographical development. – MS, S.O.M. Baghdad.

– (1979): Heavy minerals of Quaternary and pre-Quaternary sediments in the deep boreholes between Mahmudia and Mandali (Mesopotamian Plain). – MS, S.O.M. Baghdad.

– (1979): The results of the Quaternary sediments investigation in the northern part of the Mesopotamian Plain. – MS, S.O.M. Baghdad.

PHILIP, G. (1968): Mineralogy of recent sediments of Tigris and Euphrates rivers and some older detrital deposits. – J. sed. Petrology, 38, 35–44. Tulsa.

Paleogeografie kvartéru severní části Mezopotámie

(Résumé anglického textu)

DAGMAR MINAŘÍKOVÁ

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V letech 1978 a 1979 pracovala autorka pro State Organization for Minerals (S.O.M.) v Bagdádu na výzkumu kvartéru severní části Mezopotámie. Tamní kvartérní sedimenty jsou reprezentovány převážně jemnozrnnými písky, silty a jíly. Bylo zjištěno, že analýzy těžkých minerálů jsou jedinou vhodnou metodou pro rozlišení různých typů sedimentů. Proto bylo prostudováno více než 300 vzorků z mělkých i hlubších vrtů (jejich lokalizace je uvedena na obr. 2) ze sedimentů řek Adhaimu, Diyaly, Tigridu a Eufratu, dále z přiúpatních uloženin pohoří Zagrosu, ze sedimentů formace Mahmudia a z předkvartérních sedimentů (výsledky analýz jsou uvedeny v tabulkách 1–8 a na obr. 13 a 14).

Vůdčími minerály pro rozlišení různých typů sedimentů jsou zakalené minerály, horninové úlomky, obecný a čedičový amfibol, augit, titanaugit a granát. Vedle složení byla velká pozornost věnována i stupni koroze zrn pyroxenů a amfibolů, případně granátu. Pozorovatelné rozdíly v korozi zrn těchto minerálů závisí na stáří sedimentu. Pomocí koroze byly v hlubších vrtech rozlišeny tři různě staré jednotky sedimentů Tigridu – svrchnopleistocenní, starší, pravděpodobně středopleistocenní („older Tigris“) a nejstarší(„oldest Tigris“), které nelze zatím přesněji stratigraficky zařadit.

Výsledky studia těžké frakce poskytly základní data potřebná pro úvahy o paleogeografickém vývoji území. Na obrázcích 15–17 je schematicky znázorněno rozšíření studovaných sedimentů v holocénu a ve svrchním a středním pleistocénu. Severní část území, které je pokryto sedimenty řeky Adhaimu, neprodělala během holocénu a svrchního pleistocénu žádné podstatné změny. Rozšíření přiúpatních sedimentů v území mezi Mandali a Badrou se výrazně měnilo: nejmenší rozsah mělo během středního pleistocénu, zatímco v průběhu svrchního pleistocénu a holocénu se nápadně rozšiřují směrem k jihozápadu a jihu, takže překrývají středopleistocenní sedimenty Tigridu. Ty zasahovaly ve středním pleistocénu více než 100 km od dnešního toku směrem k východu a severovýchodu. Sledujeme-li rozšíření sedimentů Tigridu, vidíme, že se od středního pleistocénu posunují setrvale k západu a jihozápadu. Řeka Diyala ukládala své sedimenty ve svrchním pleistocénu a pravděpodobně i dříve východně od dnešního toku a její ústí do Tigridu leželo jv. od Baquby. V holocénu se Diyala posunula směrem k západu, její ústí do Tigridu leží na jih od Bagdádu a její sedimenty tvoří povrch velké části severní Mezopotámie, kde překrývají svrchnopleistocenní sedimenty Tigridu. Rovněž sedimenty Eufratu se posunují od východu k západu. Svrchnopleistocenní uloženiny Eufratu pokrývají území na východ od dnešního toku. V oblasti Mahmudie došlo k přemístění toku Eufratu k západu až v historické době.

Z tohoto přehledu je patrné, že všechny řeky v severní části Mezopotámie přesouvaly své toky v průběhu pleistocénu a holocénu směrem k západu a jihozápadu. Příčinou tohoto stěhování je pravděpodobně postupné zdvíhání pohoří Zagros na hranicích mezi Irákem a Iránem. Pro tento předpoklad svědčí i rozšiřování přiúpatních sedimentů.

K nejintenzivnější akumulaci dochází v mladší fázi svrchního pleistocénu a v holocénu v oblasti Mahmudie, kde byly zjištěny smíšené sedimenty Tigridu a Eufratu tohoto stáří až do hloubky kolem 50 m. Tato mohutná akumulace mohla být podmíněna buď subsidencí, nebo zvýšenou dotací klastického materiálu, vyvolanou silnou erozí a denudací ve zdrojové oblasti.

Vysvětlivky k obrázkům

1. Vymezení studovaného území.
2. Lokalizace studovaných mělkých (SBH) a hlubších (DBH) vrtů.
3. Relativní četnost opakních minerálů. 1 – sedimenty Tigridu; 2 – sedimenty Eufratu; 3 – sedimenty Diyaly; 4 – sedimenty přiúpatní zóny.
4. Relativní četnost zakalených minerálů. Vysvětlivky viz obr. 3.
5. Relativní četnost horninových úlomků. Vysvětlivky viz obr. 3.
6. Relativní četnost minerálů zoisit-epidotové skupiny. Vysvětlivky viz obr. 3.
7. Relativní četnost obecného amfibolu. Vysvětlivky viz obr. 3.
8. Relativní četnost augitu a titanaugitu. Vysvětlivky viz obr. 3.
9. Relativní četnost granátu. Vysvětlivky viz obr. 3.
10. Trojúhelníkový diagram ukazující zastoupení zakalených minerálů, horninových úlomků a obecného amfibolu. 1 – sedimenty Tigridu; 2 – sedimenty Eufratu; 3 – sedimenty Diyaly; 4 – sedimenty přiúpatní zóny.
11. Histogramy hlavních těžkých minerálů (TM) v sedimentech DBH 1. 1 – minerály zoisit-epidotové skupiny; 2 – skupina amfibolů (*spodní část sloupce* hnědý amfibol, *svrchní část sloupce* zelený obecný amfibol); 3 – skupina pyroxenů (*spodní část sloupce* ortopyroxeny, *střední část sloupce* titanaugit, *spodní část sloupce* augit a diops. augit); 4 – horninové úlomky; 5 – zakalené minerály; 6 – opakní minerály; 7 – granát.
12. Histogramy hlavních TM v sedimentech DBH 2. Vysvětlivky viz obr. 11.
13. Histogramy hlavních TM v sedimentech DBH 4. Vysvětlivky viz obr. 11.
14. Histogramy hlavních TM v sedimentech DBH 5. Vysvětlivky viz obr. 11.
15. Rozšíření holocenních sedimentů Tigridu, Eufratu, Adhaimu, Diyaly, sedimentů přiúpatní zony a uloženin formace Mahmudia. 1 – sedimenty Tigridu; 2 – sedimenty Eufratu; 3 – sedimenty Adhaimu; 4 – sedimenty Diyaly; 5 – sedimenty přiúpatní zony; 6 – sedimenty formace Mahmudia; 7 – sedimenty umělých kanálů.
16. Rozšíření svrchnopleistocenních sedimentů. Vysvětlivky viz obr. 15.
17. Rozšíření středopleistocenních sedimentů. Vysvětlivky viz obr. 15.

Vysvětlivky k tabulkám

Tabulka 1. TM v sedimentech oblasti Muqdadie a Baquby.
Tabulka 2. TM v sedimentech oblasti Bagdadu a Baladruzu.
Tabulka 3. TM v sedimentech oblasti Mahmudie.
Tabulka 4. TM v sedimentech mezi Mahmudií a Mandali.
Tabulka 5. TM v sedimentech mezi Hillou a Mandali.
Tabulka 6. TM v sedimentech oblasti Kutu a Badry.
Tabulka 7. TM v sedimentech oblasti Hashimie a Badry.
Tabulka 8. TM v sedimentech hlubších vrtů mezi Mahmudií a Mandali.

Table 1. Heavy minerals in the sediments of the Muqdadiya and Baquba arca

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
1	2B11	6.8 - 7.4	25.7	26.1	17.4	16.2	2.8	0.4	0.4			0.8	0.4	0.4	0.4	0.4		0.4	1.2	3.2			0.4		0.4	3.2			Adhaim R.
1	2B11	14.0-14.4	26.0	13.5	19.6	22.1	5.6	0.3				1.3		0.5	0.3	0.2	0.4		0.3	5.6			0.2			3.8		0.5	Adhaim R.
2	2B11	10.0-11.0	15.4	11.2	24.0	37.5	5.0	0.9	0.3			0.6			0.3	0.3	0.3		0.3	2.1					0.3	1.2		0.3	Adhaim R.
3	2B11	15.0-15.5	16.1	15.6	27.1	31.7	2.0	0.5				0.5				0.5				4.5		0.5		0.5		0.5			Adhaim R.
3	2B11	18.0-19.0	23.1	13.9	19.2	25.7	4.7	2.4	0.3	0.5	0.3	2.1	0.3	0.3	0.3	0.3		0.3	0.5	4.5				0.3	1.0	0.3			Adhaim R.
8	2B8	3.7-3.9	12.3	8.5	7.2	61.1	5.5					0.7				0.3			1.4	1.7					0.3	0.3			Adhaim R.
8	2B8	16.5-17.2	16.3	11.1	14.8	25.9	13.3	0.7			0.7	6.7	0.7					0.7		5.2						3.7			Tigris+Adhaim R.
4	2B12	9.2-9.5	20.8	15.3	19.0	33.6	1.8	0.4		0.4		0.4	0.4	0.4	0.4	0.4			0.4	5.1					0.7	0.7		0.4	Adhaim R.
5	2B12	2.3-2.6	14.2	14.2	8.5	50.1	3.0	0.9				1.2		0.3		0.3		0.3	0.6	2.1			0.3		0.3	2.4	0.3	0.9	Adhaim R.
5	2B12	10.7-11.0	11.8	12.4	21.3	42.9	2.9	1.0	0.3	0.3		1.0				0.3			0.6	2.5					0.6	1.3		0.6	Adhaim R.
6	2B12	13.0-13.5	21.2	15.0	20.2	31.9	1.0	1.3			0.3	0.8	0.3		0.3	0.3	0.2		0.3	2.6			0.2		0.5	2.6		1.0	Adhaim R.
15	2B16	4.7-5.0	17.8	19.3	24.9	25.5	2.4	0.9			0.3	0.3		0.3	0.3	0.3		0.3	0.6	3.0				0.3	0.9	2.1		0.6	Adhaim R.
13	2B16	11.8-11.9	11.7	10.9	21.2	18.3	11.7	3.6	0.7		3.9	7.3	7.3	1.5						0.7						0.7	1.5		Diyala R.
9	2C5	19.5-20.0	14.1	9.1	22.8	22.5	10.6	1.9	0.3	0.3	0.3	4.1	0.3	1.9	0.3	0.3	0.3		0.3	9.4			0.3		0.3	0.3			Tigris R.
10	2C5	18.5-19.5	19.2	8.0	15.3	26.4	10.4	1.5		0.2	0.5	3.4	0.5	0.5	0.5			0.2	0.3	9.2	0.2				0.5	2.7	0.5		Tigris R.
11	2C9	7.2-7.4	18.1	6.2	20.1	18.1	13.5	3.5		0.4	2.3	5.4	3.9	0.8					0.4	0.4		0.4				5.0		1.2	Diyala R.
12	2C9	10.0-10.4	17.3	8.8	18.4	20.5	10.1	3.0		0.5	1.6	4.9	7.4	0.5	0.3	0.3	0.3	0.3	0.3	1.4					0.5	1.9		1.6	Diyala R.
30	2C13	8.8-9.5	40.8	7.6	11.6	13.5	7.2	2.2	0.2	0.2	0.2	2.4	1.8	0.2	0.2	0.4	0.4	0.2	0.6	6.8			0.2		0.4	1.1		2.0	aeol.sand
30	2C13	12.4-13.4	15.9	13.2	23.4	13.6	9.0	7.5		0.6		3.3	6.6	0.9	0.3	0.3			0.3	1.8					0.3	0.9			"older"Diyala R.
31	2C13	11.0-12.5	31.7	5.7	20.8	9.2	5.4	2.0		0.3	1.0	4.0	15.6			0.3		0.3	0.5	2.2					0.7	0.3	0.3		"older"Diyala R.
52A	2C13	5.4-5.7	14.7	8.1	21.8	19.8	10.9	5.1		0.5	1.5	4.6	3.6	1.5			0.2		0.5	1.8					0.3	3.3	1.5	0.3	Diyala R.
52A	2C13	10.0-10.2	20.0	7.9	18.3	27.9	8.2	2.2		0.5	0.7	4.1	1.2	1.2		0.2		0.2	0.7	1.4					0.2	4.6		0.5	Diyala R.
52A	2C13	11.3-11.7	15.6	5.0	22.0	27.3	9.8	3.9	0.3	0.6	0.3	5.9	1.1	0.3		0.3		0.3	0.9	2.5					0.3	2.5	0.3		"older"Diyala R.
52A	2C13	24.0-24.5	12.5	8.7	17.2	17.0	17.3	7.3	0.2	1.2	1.2	10.1	4.9	0.2		0.2			0.7	0.2					0.2	1.2			"older"Diyala R.
27	2C13	2.1-2.4	23.9	15.2	12.5	18.0	7.6	1.7	0.3			4.2	6.6	1.4	0.3	0.3		0.3	0.3	5.5					0.4	1.4			aeol.sand
27	2C13	18.2-18.5	24.9	13.2	14.3	15.9	5.4	3.5	0.3	0.5	0.3	4.1	11.9	0.5		0.3			0.8	3.5					0.3		0.3		"older"Diyala R.
28	2G1	13.5-13.6	36.3	10.4	16.5	14.7	5.2	0.5	0.2	0.2	1.1	1.6	2.7	1.1	0.2	0.2	0.2	0.5	0.5	6.7				0.2	0.2	0.7			aeol.sand
46	2G1	0.6-0.9	49.0	8.1	9.6	18.4	2.6	1.7	0.3					0.3	0.3	0.3		0.3	0.3	3.5					0.3	3.2		2.3	foothill
46	2G1	10.8-11.0	38.3	10.9	11.7	19.4	1.9	1.9	0.3	0.3		0.3			0.3		0.5	0.3	0.8	4.0					0.5	2.4		6.6	foothill
53A	2G1	5.3-5.4	47.1	8.4	14.2	10.6	0.9	0.9				0.4							0.4	5.3				0.4	0.4	3.1		7.6	foothill
53A	2G1	12.2-12.5	49.8	4.4	13.0	8.9	1.2	1.2	0.4			0.4				0.4	0.4	0.4	0.4	3.2					0.4	3.6		11.3	foothill
21	2C6	18.5-19.0	14.5	8.4	12.7	24.8	15.3	1.7		0.6	0.3	4.9	0.3	1.2	0.6	0.6	0.3	0.3	0.3	10.7				0.3	0.3	2.0			"older"Tigris R.

Table 2. Heavy minerals in the sediments of the Baghdad and Baladruz area

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
53	2C3	9.5-10.0	12.6	15.8	9.9	16.7	12.1	2.7		0.3	1.5	16.3	2.2	0.2		0.2		0.2	0.3	7.4	0.2	0.2			0.5	0.5			Euphrates R.
53	2C3	16.7-17.0	13.6	19.3	8.0	21.8	9.5	1.5		1.3	1.8	14.9	2.3	1.0		0.3			0.3	3.8		0.3	0.3						Euphrates R.
53	2C3	20.8-20.9	11.8	12.6	12.6	24.0	17.4	3.1		0.3		11.5	1.0	0.3		0.3		0.3		4.1			0.3	0.3		0.3			Euphrates R.
53	2C3	29.7-29.8	25.9	10.9	8.1	23.4	5.0	0.8		0.8	0.3	1.9		0.3	0.3	0.6		0.3	1.7	18.4			0.3	0.3	0.3	0.6			Mahmudia F.
54	2C3	4.5-4.7	21.1	11.7	12.4	22.8	7.0	1.5	0.2	0.5	0.3	9.0	0.3	0.5	0.2	0.2				11.2	0.2	0.2	0.5		0.2				res.Mahmudia F.
54	2C3	7.6-7.7	9.3	9.0	8.3	26.2	23.9	2.3		1.0	1.0	12.1	5.0	0.7				0.3		2.8			0.2		0.3	1.0			Tigris R.
54	2C3	12.1-12.2	10.0	19.5	7.5	25.2	14.5	1.8		1.4	1.8	12.1	2.3	0.5	0.2	0.2			0.2	1.8		0.2		0.2	0.7				Euphrates R.
54	2C3	19.0-19.1	16.8	11.4	14.3	16.6	13.6	2.7		1.0	0.7	13.6	2.5	0.5	0.2	0.2			0.3	4.6			0.5		0.2	0.5			Euphr.+Tigris
54	2C3	21.4-21.5	13.9	7.6	12.4	21.8	19.0	1.8	0.3	1.0	1.8	10.4	1.8	0.5					0.5	5.6	0.3			0.3		1.3			Euphr.+Tigris
54	2C3	36.8-37.0	24.6	12.6	13.8	20.7	4.8	0.9		0.2	0.2	8.7	0.9		0.2					10.3		0.2	0.2	0.7	0.5	0.2			Mahmudia F.
55	2C7	6.6-6.7	11.3	6.5	7.9	13.9	30.1	5.2		0.5		3.4	0.5	0.5	0.3			0.3	1.0	3.7					0.5	14.1		0.3	Tigris R.
55	2C7	9.5-9.6	10.4	8.5	6.5	26.1	24.4	2.0	0.3	1.3	1.6	10.7	2.3					0.3	0.3	1.6					0.3	3.3			Tigris R.
55	2C7	16.7-17.0	21.4	5.9	11.1	18.1	14.1	1.4		0.7	2.4	12.0	1.9		0.5	0.2			0.5	8.9	0.2		0.2		0.5				Tigris R.
55	2C7	25.9-26.0	15.6	15.9	11.1	22.6	7.3	1.0		1.3	1.0	15.3	1.3	1.0		0.3			0.3	5.1				0.3	0.6				Tigris+Euphr.
55	2C7	32.7-33.0	19.1	10.4	14.1	19.3	11.6	1.7		0.7	0.2	6.7	1.2	1.0		0.2		0.2	0.2	11.3	0.5	0.2	0.2	0.2	0.5				Mahmudia F.
22	2C6	3.3-3.7	23.0	11.8	4.8	14.0	12.1	2.5		1.2	4.2	11.1	1.0		0.3		0.9		0.3	10.9					0.3	1.5	0.3		Tigris R.
22	2C6	17.6-17.8	9.1	11.4	8.4	23.4	14.7	2.3	0.3	3.6	3.6	13.7	0.6		0.6		0.3	0.6	1.0	6.1					0.3	0.3	0.3		Tigris R.
23	2C6	6.5-6.8	14.3	5.8	20.1	14.2	5.8	1.4		1.1	0.4	5.2	0.4							2.6					1.1	1.1	1.1	25.0	Tigris R.
23	2C6	17.7-18.0	28.1	15.8	6.4	12.4	4.5	0.8		0.3	4.2	15.3	0.3			0.5		0.3	0.3	10.1				0.3	0.3	0.3			Tigris R.
59A	2C7	3.4-3.6	13.7	5.9	11.6	18.8	23.3	1.8		0.9	0.3	2.1	1.8		0.3	0.3		0.3	0.3	5.7					0.3	10.1	2.4	0.3	Tigris R.
59A	2C7	14.1-14.2	8.8	10.7	17.1	15.8	20.1	2.7		0.6	1.8	12.8	1.2	0.6	0.3	0.3		0.3		5.2		0.3		0.3	0.3	0.3		0.3	Tigris R.
59A	2C7	20.2-20.5	11.8	14.8	14.8	20.4	12.5	2.3		0.3		8.9	0.7	0.7		0.3		0.3	0.3	9.9	0.3				0.3	1.0	0.3		"older"Tigris R.
59A	2C7	26.0-27.0	17.3	11.2	15.6	17.8	10.0	1.6		1.4	0.5	4.9	1.4	0.3		0.3		0.3	0.8	11.2			0.3	0.3	0.3	4.4			"older"Tigris R.
20	2C10	6.7-7.0	16.9	4.6	13.3	22.7	11.7	4.2			5.2	16.2	2.0				0.3		1.0	0.6			0.3			1.0			Diyala R.
20	2C10	16.3-16.6	7.8	7.6	10.8	16.0	25.2	2.0		1.7	1.0	14.7	5.4	1.2		0.2	0.2		1.0	3.2			0.3	0.3	0.5	1.0			Tigris+Diyala
18	2C10	10.0-10.2	10.1	14.6	20.1	17.5	8.2	3.9			2.3	16.5	3.0						2.0	1.6						0.3			Diyala R.
18	2C10	18.8-19.0	14.8	8.4	7.9	24.6	18.3	2.5			3.2	7.7	0.2		0.2	0.2		0.5	2.2	5.6			0.2	0.7	0.2	1.2		0.9	Tigris R.
17	2C10	4.6-4.9	10.5	3.8	14.2	23.8	7.0	3.5			6.7	18.2	5.0					0.6	1.6	1.2			0.3		0.3	1.9		1.6	Diyala R.
17	2C10	15.7-16.0	19.2	11.5	8.2	19.5	17.2	2.7	0.2	1.3	0.4	7.9	1.6	0.4		0.2			0.7	6.8		0.2	0.2		0.5	1.4			Tigris R.
24	2C14	11.7-11.9	10.1	8.6	12.8	27.2	15.9	2.3			3.5	14.3			0.4				1.6	1.1						0.8		1.6	Diyala R.
24	2C14	15.3-15.5	13.3	7.7	33.4	16.1	11.3	1.7		0.3	2.5	8.1	0.3						0.7	0.7						3.8			Diyala R.
26	2C14	5.8-6.0	17.3	4.2	19.8	26.5	10.9	2.2		0.6	0.6	6.1	3.6	0.6		0.3		0.3	0.8	2.8		0.3			0.3	2.8	0.3		Diyala R.
25	2C14	4.2-4.4	10.3	4.6	17.7	15.1	26.2	4.0		0.8	0.6	3.7	1.1	0.8	0.6	0.3			1.1	1.7				0.3	0.3	9.4	1.4		Diyala R.
25	2C14	17.0-17.2	22.1	8.3	18.5	18.8	6.9	1.7		0.7	1.1	5.6	10.6	0.3				0.3	1.0	2.3					0.7	0.3			"older"Diyala

Table 3. Heavy minerals in the sediments of the Mahmodiya area

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
44	2D1	5.5-5.6	18.4	9.9	8.2	20.2	19.9	4.6		0.7	1.2	6	0	0.7			0	0		6		0		1		2			Mahmudia F.
44	2D1	20.0-20.1	17.4	22.8	4.6	18.9	14.3	4.1		0.4		6.5		0.7	0	0	0	0	1	5		0	0	1	0	2	0		Mahmudia F.
45	2D1	0.8-3.3	20.1	17	8.3	11.6	10	4.4		0.2	1.2	19.4	1	1.2	0	0				3			0	1		1	0		Euphrates R.
45	2D1	5.6-5.7	18.6	21.4	4.6	15.7	7.7	3.6		1	0.8	14.2	0	0.8		0	0	0	0	8		0	1		0	1		0.3	Euphrates R.
45	2D1	12.2-12.3	21.1	22.2	6.5	21.4	7.9	4.8			0.3	4.2		0.3	1	0			0	8	0	0	1	1		0			Mahmudia F.
45	2D1	16.1-16.2	14.3	30	8.2	21	8.8	3.4	0	0.3	0.8	4.5		0.3						4		1	1	1		2			Mahmudia F.
42	2D1	9.3-9.4	6.1	11.7	3.5	22.8	24.8	3.2		0.6	1.2	16.3	1			1			1	4			0			2		2	Euphrates R.
42	2D1	12.4-12.5	9.1	16.2	6.9	27.6	17.5	2.9	0	0.8	0.4	6.4	0	0.8		0		0	1	3		0		0	0	5			Mahmudia F.
42	2D1	15.5-15.6	18	22.4	6.3	19.9	11.4	4.7		0.3		4.1	0		0	1		1	1	6			0	1	0	3			Mahmudia F.
42	2D1	19.6-19.7	24.1	20.8	5	11.8	11.9	3		0.3	0.3	5.3		0.3		0		0	1	9		1		1		2			Mahmudia F.
42	2D1	19.9-20.0	22.2	18.3	6.9	15.9	10.8	3.9		0.3	1.5	14.4	0	0.9		0				4						1			Mahmudia F.
42	2D1	24.9-25.0m	8.1	12.2	8.4	19.5	5.1	2.7				2.2	0	0.3	0	0		0	1	4			1	2		1	0	33.0	pre-Quaternary
41	2D1	4.5-4.6	18.2	21.1	6.4	15.4	10.1	2.7		0.5	1	11.5		0.7	1	0		0	0	8		0	1	1	0	2			Euphrates R.
41	2D1	8.5-8.6	15.6	24.2	15.9	16.6	8	4.2				7.3		0.4				0	1	3	0			1		2	0		Mahmudia F.
41	2D1	16.1-16.2	16.8	14.9	7	17.7	11.1	6.1		0.9	0.7	9.6		1.4	0	0		0	0	9			0	0	0	2		0.2	Mahmudia F.
41	2D1	17.2-17.3	25.3	14	5.4	24.3	8	5		0.3	0.3	3		1.4				1		9	0		0	0		3			Mahmudia F.
38	2D5	7.7-7.8	25.1	13.1	4.7	19.9	12.9	2.3	0.2			8.7	0.2	1.2	0.2	0.5			0.7	8.0		0.2	0.2	0.5		1.2			Mahmudia F.
38	2D5	11.4-11.5	18.9	26.2	7.6	17.9	12.3	3.6	0.4		1.1	5.1							0.4	2.2		0.4	1.1	1.1		0.4	0.4		Mahmudia F.
38	2D5	25.8-26.6	8.7	21.4	9.6	18.9	14.4	3.6		1.7	0.4	13.6		0.7	0.2	0.2			0.2	4.9		0.2	0.2	0.2	0.2	0.4			Mahmudia F.
37	2D5	2.5-3.2	23.2	24.3	2.7	12.0	5.1	2.9		0.3	2.1	17.9	1.3	1.1					0.3	5.3		0.3	0.5	0.3		0.5			Euphrates R.
37	2D5	18.0-19.0	27.6	15.2	5.5	17.6	15.5	3.6	0.3	0.3	0.3	3.0	0.3			0.3		0.3		5.1	0.3		0.3		0.3	3.9			Mahmudia F.
34	2C8	6.5-6.6	5.6	4.6	11.6	19.0	38.4	2.8		1.8	0.7	9.5	0.3							1.4					0.3	3.2	0.7		Euphr.+Tigris
34	2C8	10.6-10.7	13.1	9.3	10.0	17.9	24.4	1.7		0.3	0.3	17.2	1.4	0.3	0.3				0.3	1.3						2.1			Euphr.+Tigris
34	2C8	12.6-12.7	9.7	18.8	5.7	17.0	19.7	1.6		1.1	1.8	16.1	2.0	1.4				0.2	0.2	2.5		0.2	0.2	0.5	0.5	0.9			Euphr.+Tigris
35	2C8	5.6-5.8	10.2	7.8	2.9	23.3	23.3	2.2	0.4	2.2	2.7	16.0	3.6	1.3	0.2	0.2	0.2		0.2	1.3				0.2	0.2	1.3		0.2	Euphr.+Tigris
35	2C8	7.5-7.6	11.3	18.3	13.7	15.4	17.1	2.9			1.3	14.2	0.8	1.3				0.4	0.4	1.7						1.3			Euphr.+Tigris
35	2C8	15.5-15.6	12.6	22.0	7.4	23.4	11.0	2.2		2.0	1.0	10.0	0.2	1.0	0.2				0.6	4.8		0.4		0.2	0.6	0.4			Euphrates R.
35	2C8	20.0-22.4	13.0	19.2	10.8	17.5	11.4	0.8		0.8	1.1	17.8	0.8	1.1		0.3			0.3	4.6		0.3	0.3						Euphr.+Tigris
36	2C12	14.5-15.1	9.6	11.6	9.1	19.9	24.5	2.0		1.4	0.3	8.8	1.4	2.6		0.3		0.3	0.6	1.4		0.3	0.3	0.6		4.8			Tigris R.
22	2D9	8.1-11.3	15.8	14.5	7.6	18.1	17.1	3.3		1.3	0.6	13.5	1.3	1.0			0.3	0.3		4.2		0.3		0.3	0.3				Euphrates R.
22	2D9	15.1-15.2	17.5	10.7	16.0	19.3	13.6	1.8	0.3	0.9	0.6	8.6	2.4	0.9	0.3	0.3		0.3	0.3	3.8			0.6	0.3	0.3	1.5			Tigris R.
21	2D9	13.6-13.7	21.7	5.4	10.8	19.6	25.0	3.9	0.3	0.3		6.0	0.3	0.3		0.3			0.6	2.7			0.3			2.4			Tigris R.

Table 4. Heavy minerals in the sediments of thearea between Mahmodiya and Mandali

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
32	2C11	2.7-3.0	14.6	10.2	10.7	10.6	7.3	3.2		1.5	0.3	36.0	2.0		0.5	0.2			0.5	1.2			0.2		0.5		0.2	0.2	Diyala R.
32	2C11	15.8-16.0	11.4	13.2	10.8	15.5	12.6	3.2	0.3	1.6	2.0	19.0							0.6	7.9			0.3		0.3	0.6		0.3	Tigris R.
1	2C12	13.0.13.2	17.4	13.2	7.7	19.5	11.3	2.7		2.2	3.9	11.6	3.6	1.1	0.3	0.3		0.3	0.8	3.0	0.3					0.3	0.3	0.3	Tigris+Diyala R.
3	2C12	10.8-11.0	10.9	12.2	12.4	16.2	16.5	2.3	0.2	3.5	2.0	17.5	0.8	1.5					0.3	1.3		0.2		0.2	0.2	1.3	0.2		Tigris+Diyala R.
3	2C12	13.7-14.0	11.6	12.6	6.4	21.5	13.4	3.0		1.5	1.3	17.9	1.8	3.3	0.2		0.2		0.2	4.3				0.2	0.2	0.5			Tigris+Diyala R.
2	2C12	7.0-7.1	21.9	9.8	4.8	19.6	19.8	3.6		2.3	0.5	5.2	0.9	1.1		0.2		0.2	0.7	3.9	0.2				0.7	3.9	0.2		Tigris+Diyala R.
2	2C12	13.1-13.2	15.4	11.1	15.1	19.6	12.0	1.2		3.3	3.0	11.4	1.8	2.4		0.3			0.3	2.1						0.3	0.3	0.3	Tigris+Diyala R.
2	2C12	14.9-15.0	19.2	11.3	3.7	22.6	13.0	1.1	0.3	2.0	1.7	13.6	2.3	0.8		0.3		0.3	0.6	4.8				0.3	0.6	1.7			Tigris+Diyala R.
4	2C12	3.9-4.0	16.6	16.9	11.0	17.9	7.8	1.9		1.6	0.9	7.8	11.6	2.3			0.3			1.6						0.6	0.3	0.3	Diyala R.
4	2C12	7.8-8.0	20.0	5.2	16.2	22.7	12.1	3.1			0.3	7.2	1.0	1.0					1.7	4.1						3.4	0.7	0.7	Tigris+Diyala R.
4	2C12	17.3-17.4	13.9	11.4	12.6	20.0	13.4	2.3	0.2	2.3	1.0	10.9	2.3	1.5	0.3	0.2			0.5	6.0					0.5	0.3			Tigris R.
5	2C16	10.0-11.0	16.2	13.0	10.5	16.1	11.2	2.5	0.2	1.8	0.7	11.4	3.2	2.7		0.2		0.2	0.5	9.0			0.2		0.5	0.2			Tigris R.
5	2C16	13.6-14.0	19.8	10.6	8.3	15.9	16.4	4.3		2.3	0.3	6.3	2.9	2.6	0.3	0.6		0.6		6.0			0.6	0.3	0.3	1.7			Tigris R.
5	2C16	18.3-18.4	13.8	5.1	13.8	24.5	17.1	1.4			1.4	11.2	2.2	0.8	0.3		0.3		0.3	4.8			0.8	0.6		1.4	0.3		Tigris R.
42	2C15	4.0-4.2	17.5	13.6	9.6	22.1	7.7	3.1		0.8	1.3	16.0	2.0						1.0	3.3			0.3		0.5	0.5		1.0	Tigris+Diyala R.
42	2C15	10.4-11.0	10.2	5.8	8.7	17.3	30.7	3.5	0.3	0.9	1.2	5.5	0.3	0.6		0.3				1.2				0.3		11.0	2.3		Tigris+Diyala R.
42	2C15	15.0-15.3	11.9	7.6	8.1	15.5	17.3	2.3		3.0	2.5	23.4	2.0			0.3		0.5	0.3	2.5		0.3	0.3		0.3	0.8	0.3	0.5	Tigris+Diyala R.
37	2G3	15.7-16.0	13.8	5.8	12.7	32.6	12.4	1.2			2.2	9.6	0.3		0.8	0.3		0.5	2.2	3.3			0.5	0.3	0.3	0.8		1.4	Tigris+Diyala R.
37	2G3	19.8-20.0	18.5	10.8	7.5	15.3	14.4	3.3	0.3	3.0	1.4	13.6	0.3		0.3				1.7	7.5				0.3	0.3	0.8		1.1	"older"Tigris R.
36	2G3	4.7-4.8	16.7	14.5	7.9	18.4	6.3	2.1			4.8	19.6	4.0			0.3			0.3	3.0			0.3		0.6	0.6			Tigris+Diyala R.
36	2G3	18.0-18.2	21.7	8.8	11.4	18.9	9.8	2.1		2.3	2.1	8.5	0.8		0.8	0.2	0.2	0.2	0.5	10.9				0.2	0.5		0.5		"older"Tigris R.
45	2G6	18.4-18.5	45.6	6.2	9.3	13.6	1.0	1.0		0.7	0.2	1.2			0.2		0.5		1.2	1.5			0.2		0.2				foothill
48	2G6	19.2-19.5	72.6	3.4	4.2	5.6	4.2	1.1	0.2	1.1	0.8	3.1			0.2	0.2		0.2	0.2	0.6					0.3	1.3	0.5		foothill
49	2G10	6.7-6.9	20.5	5.1	4.5	6.3	1.8	0.7	0.1	1.8	0.8	3.3			0.2	0.2		0.3	0.3	0.3		0.2	0.2		1.0		0.3	53.8	foothill
49	2G10	16.3-16.5	48.4	4.6	10.2	18.8	0.3	0.3			0.6	1.4			1.0	0.7	0.7	0.3	2.1	3.2			1.4		1.0			5.0	foothill
20	2D9	15.3-15.4	14.8	13.4	18.2	15.1	13.1	3.1		1.4	0.6	9.4	2.0	0.3	0.6	0.6			0.3	5.1		0.3			0.8	1.1			Tigris R.
20	2D9	19.8-19.9	17.9	9.2	18.2	15.3	15.0	2.3	0.3	0.6	1.4	10.4	2.3	0.9		0.3		0.3	0.3	4.0				0.3	0.3	0.3			Tigris R.
6	2C16	7.2-8.0	12.7	13.7	8.2	20.8	13.5	2.1	0.3	0.5	2.9	12.7	2.1	2.1		0.3		0.3	0.3	6.9		0.3	0.3		0.3				Tigris R.
6	2C16	15.5-16.7	17.8	10.9	11.6	14.2	14.6	4.7	0.2	2.0	0.2	9.9	1.5	3.5		0.5		0.2	0.5	5.9			0.5		0.7	0.5			Tigris R.
7	2C16	10.4-10.5	11.6	26.5	8.9	15.0	10.6	1.0		1.7	1.7	11.6	2.0	1.7	0.3	0.3		0.3	0.3	4.6		0.3	0.3	0.3		2.0			Tigris R.
39	2G3	19.5-19.7	23.7	4.0	12.7	11.9	18.2	3.0			1.3	7.5	2.5	0.7		0.3		0.3	0.3	10.7			0.2	0.2	0.5	2.0			"older"Tigris R.

Table 5. Heavy minerals in the sediments of the area between Hilla and Mandali

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
61	2D7	8.1-8.2	19.6	13.2	6.7	15.9	20.2	4.4			0.3	5.3	0.3			0.3		0.3	0.6	5.9						6.4	0.6		res.Mahmudia F.
61	2D7	10.3-10.4	10.0	19.2	7.3	19.7	14.6	1.8		0.6	3.0	16.7	2.4	0.3					0.6	2.4						1.2			Euphrates R.
61	2D7	17.3-17.5	22.9	14.4	7.9	24.4	14.1	2.3			0.3	2.3			0.3	0.6		0.3	0.3	8.2	0.3			0.3	0.3	0.8			Mahmudia F.
60	2D7	4.2-4.3	6.9	9.3	5.9	20.6	34.3	3.7		0.3	1.6	10.0	1.6	0.3					0.3	1.6		0.3				2.5	0.3	0.6	art.canal
60	2D7	9.1-9.2	16.1	13.6	7.3	19.0	13.0	2.2		0.3	1.6	18.4	3.2			0.3			0.3	4.1						0.3			Euphrates R.
60	2D7	12.7-12.8	10.7	11.9	6.1	19.8	24.7	3.4		0.3	1.2	12.5	0.9	0.6					0.6	2.7		0.3				2.7	1.5		Euphrates R.
60	2D7	14.2-14.3	13.0	13.6	7.7	18.9	20.7	2.2		0.3	0.6	13.6	1.6		0.3	0.3	0.3	0.3	0.6	4.0		0.6		0.3	0.3	0.6			Euphrates R.
60	2D7	19.5-19.6	19.3	17.7	7.0	22.0	8.6	2.5		0.3	0.3	16.8	0.6	0.3		0.3				3.1		0.3			0.3	0.6			Euphrates R.
59	2D7	3.0-3.1	10.8	11.1	8.7	17.1	24.9	4.8		0.3	2.4	11.4	1.2	0.6	0.3				0.3	2.1				0.3	0.3	3.0	0.3		art.canal
59	2D7	6.9-7.0	14.4	17.7	9.0	18.0	22.8	3.0		0.6	1.2	9.3	1.5						0.3	1.8						0.3			art.canal
59	2D7	17.4-17.5	26.9	19.4	5.9	22.5	3.4	1.6		0.3		0.6		0.3	0.6	3.4		0.3	1.6	12.2			0.3	0.3	0.3				res.Mahmudia F.
59	2D7	21.0-21.1	7.9	33.8	9.4	16.9	10.5	0.8		0.4	0.4	12.8	1.1	0.8					0.7	2.3	0.4	0.7		0.7		0.4			Euphrates R.
28	2D13	19.1-19.2	16.2	10.5	10.8	15.3	22.9	3.4	0.3	0.3	0.3	5.9	0.3	0.3	0.3	0.3	0.3	0.6	0.3	7.4		0.3	0.3		0.3	3.7			"older"Tigris R.
27	2D13	13.0-13.2	13.5	14.1	16.2	24.3	10.5	1.2	0.3	0.6	0.9	8.1	0.6	1.2	0.3	0.3		0.3	0.6	4.5	0.3	0.6	0.3		0.6	0.6			Tigris R.
27	2D13	17.6-17.7	16.1	8.3	12.2	15.9	16.7	2.6		1.3	1.0	13.5	1.6	1.6		0.5	0.3	0.3		6.0				0.3	0.8	0.5	0.5		Tigris R.
12	2G4	18.6-18.8	18.3	12.2	12.2	25.1	15.9	1.5		0.9	1.2	3.4	0.9			0.3		0.6		5.2	0.3		0.3	0.3		0.5	0.3		Tigris R.
77A	2G7	14.4-14.5	59.1	3.7	9.4	10.0	0.7	0.3				0.7							0.3	4.4		0.3			0.7	1.0		9.4	foothill
77A	2G7	19.8-20.0	15.3	7.7	6.5	27.5	15.9	3.1	0.3	0.3	1.1	7.9	1.1		0.6	0.6		0.3	0.6	6.8	0.3	0.3	0.3		0.9	2.3	0.3		"older"Tigris R.
62	2D8	6.3-6.4	6.5	9.8	8.2	14.8	32.0	2.0		0.3	0.7	12.4	1.0			0.3			0.6	0.3						8.2	2.9		art.canal
62	2D8	12.2-12.3	10.2	2.7	5.1	13.0	25.6	4.1			0.3	7.2	0.3		0.3	0.3			0.3	0.3						22.2	7.9		art.canal
62	2D8	15.0-15.1	17.4	10.6	7.6	19.7	18.5	3.2		0.9	2.1	13.5	1.5			0.3	0.3		0.3	2.6					0.6	0.3		0.6	Euphrates R.
26	2D14	10.7-10.8	8.5	6.6	16.8	20.1	20.9	1.7		1.4	1.7	13.8	0.6	0.6			0.6	0.3	0.6	2.5	0.3		0.3		1.1	1.7	0.3		Tigris R.
24	2D14	10.7-10.8	10.8	11.3	14.8	22.3	19.3	3.0		0.5	1.5	8.3	1.5	0.3		0.3	0.3	0.5	0.5	3.6			0.3		0.3	1.0			Tigris R.
82A	2G8	12.6-12.7	8.4	14.4	10.5	23.1	21.7	3.4	0.3	1.0	1.0	8.9	0.3	0.3	0.5				0.3	2.8		0.2				2.9			Tigris R.
82A	2G8	17.6-17.7	14.4	19.7	7.5	29.5	7.9	2.5		0.6	0.3	7.9	0.3	0.3				0.3		7.2						1.6			Tigris R.
80A	2G8	5.0-5.1	78.3	2.8	6.8	5.3	1.4	0.4				0.4							0.3	0.7					0.7	1.1		1.8	foothill
80A	2G8	16.0-16.1	19.2	4.8	9.9	19.2	17.8	2.5	0.3	0.3	1.1	2.8	0.6	0.6	0.3		0.5	0.3	0.3	3.4	0.3					12.7	3.1		"older"Tigris R.
76A	2G11	1.4-1.5	74.4	4.0	6.2	4.9	1.5	0.6	0.3			0.3						0.3	0.3	0.9					0.3	1.5		4.4	foothill
76A	2G11	14.8-15.2	63.1	8.0	7.4	9.7	0.6	0.9				0.9			0.3	1.2		0.3	1.2	2.0				0.2	1.7	1.8		0.6	foothill
76A	2G11	18.2-18.5	76.1	4.4	5.5	3.2	0.3	0.3			0.3	0.6				0.6	0.3	0.3	0.3	1.2					0.6	1.2		4.9	foothill
75A	2G11	1.7-2.0	71.4	4.5	2.2	4.9	1.8	0.4					0.4	0.4		0.9		0.4	0.4	3.6					1.4	1.4	0.9	4.9	foothill
75A	2G11	12.5-13.0	70.0	3.5	5.0	12.4	1.2	0.8	0.4			0.4				1.6		0.4		1.6					0.8	0.8		1.2	foothill
75A	2G11	19.7-20.0	79.0	2.3	3.9	3.1	1.8	1.0			0.3	0.3				0.3				1.0					0.8	2.3		3.9	foothill

Table 6. Heavy minerals in the sediments of theKut and Badra area

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
68A	2H10	2.1-2.2	16.5	11.1	13.9	19.0	16.1	1.6		0.6	0.9	8.9	1.9		0.6			0.3		2.1					0.6	5.7			Tigris R.
68A	2H10	9.1-9.2	15.3	6.8	11.2	20.7	19.2	3.2		0.9	2.0	7.4	1.2	0.3	0.3	0.3	0.3	0.6	1.2	4.1		0.3		0.3	0.3	4.1	0.3		Tigris R.
68A	2H10	13.4-13.5	16.5	9.1	14.6	20.6	14.3	3.0		1.1	0.5	6.3	2.2		0.3				0.3	7.9		0.3				2.5	0.5		Tigris R.
68A	2H10	16.4-16.5	20.1	10.5	12.6	21.3	11.7	1.8		0.6		6.6	2.1		0.3	0.3		0.3	0.6	7.5	0.3			0.3	0.9	2.1			Tigris R.
67A	2H9	3.6-3.7	14.9	6.7	13.6	20.3	19.4	3.9			0.9	3.9	3.3		0.3	0.3	0.6	0.6		5.5				0.6	0.3	4.9			Tigris R.
66A	2H9	12.1-12.2	14.2	11.1	13.1	27.6	12.2	3.4		0.6	0.6	4.3	1.1	0.3	0.6		0.3		0.8	6.2						3.4	0.3		"older"Tigris R.
65A	2H9	13.9-14.0	11.5	8.5	15.1	16.3	25.1	1.8		0.9	1.2	7.3	2.1	0.6		0.3		0.3	0.3	0.9						6.0	1.8		Tigris R.
65A	2H9	18.5-18.6	13.1	14.2	14.8	20.7	10.7	1.9		0.5	1.1	10.9	3.0	0.6		0.3			0.3	5.7	0.3				0.5	1.4			"older"Tigris R.
63A	2G16	15.7-15.8	67.6	2.9	8.6	8.9	1.7	0.3				0.3	0.5			0.3		0.3	0.3	0.3					0.3	7.1			foothill
63A	2G16	23.8-23.9	57.0	5.9	7.6	12.4	3.1	0.6				1.7	0.3					0.3	0.3	1.9		0.3			0.3	2.2	0.8	5.3	foothill
64A	2G16	1.5-1.7	52.5	4.0	2.5	6.9	2.9	1.4				0.4				0.4		0.4	0.7	1.1						5.4	0.4	21.0	foothill
64A	2G16	4.8-5.0	32.2	7.8	4.3	18.4	8.3	0.6	0.6			2.0	0.3			0.3		0.6	0.3	2.3					0.9	5.7		15.5	foothill
74A	2H10	5.5-5.6	15.9	13.8	10.9	20.6	9.7	0.6			1.2	11.5	2.3	0.3		0.3		0.3	0.3	9.4			0.3	0.3	0.9	1.2	0.3		Tigris R.
74A	2H10	13.2-13.5	12.0	16.1	11.4	20.5	15.5	2.6			1.7	6.7	0.6	0.6			0.3		0.3	9.9	0.3			0.3	0.6	0.6			"older"Tigris R.
73A	2H10	15.8-16.0	12.5	19.2	16.4	25.4	8.1	0.3	0.3	0.3	0.8	4.4	2.2	0.3		0.3	0.3	0.5		6.1	0.3		0.3		0.3	1.7			TigrisR.
73A	2H10	18.5-18.7	12.5	7.0	12.5	28.3	13.4	3.4		0.6	0.9	7.9	1.5	0.3	0.3				0.6	8.6			0.6	0.9		0.6			"older"Tigris R.
69A	2H13	6.9-7.2	55.0	2.9	10.8	9.9	2.6	1.8				0.4				0.7		0.2	0.2	2.0					0.4	5.9	1.1	6.1	foothill
69A	2H13	18.8-19.0	17.0	3.9	12.6	17.8	20.7	1.0		0.5	1.0	7.1	1.8	0.3		0.3	0.3		0.5	6.8			0.3			6.8	1.3		"older"Tigris R.
70A	2H13	9.8-10.0	15.4	10.8	13.0	18.2	12.3	2.8	0.3		0.9	9.9	1.2			0.3		1.2	0.6	9.4			0.3			3.4			"older"Tigris R.
70A	2H13	15.7-15.9	22.5	11.0	11.3	16.8	11.0	2.6	0.3	0.3	0.3	6.6	3.2	0.3	0.9	0.3	0.3		0.3	9.8				0.3	0.3	1.7			"older"Tigris R.
71A	2H14	12.6-12.7	11.3	8.4	11.5	20.2	26.5	5.3		0.3	1.7	6.5	1.7				0.3	0.6	0.3	1.7			0.3			3.4			Tigris R.
71A	2H14	14.7-14.8	20.4	11.0	11.6	21.6	13.4	2.1	0.3	0.3	1.8	3.7	1.2	0.3		0.6			0.3	9.1	0.3				0.3	1.5			Tigris R.
71A	2H14	18.7-18.9	21.5	9.8	14.2	17.9	13.0	1.6			1.6	6.9	1.6					0.4	0.4	10.2					0.4	0.4			"older"Tigris R.
72A	2H14	4.7-4.9	19.6	10.8	13.2	17.9	13.9	1.0		0.7	1.4	6.1	0.7	0.7				0.3	0.3	8.5						5.1			Tigris R.
72A	2H14	20.4-20.8	19.7	16.8	9.8	21.2	7.8	0.6		0.3	0.6	8.1	2.3	0.6		0.3		0.3		8.7	0.3	0.3		0.3	0.3	1.7			"older"Tigris R.
97	2H15	7.9-8.0	11.8	14.2	13.9	18.5	13.3	2.0		0.3	1.5	12.4	2.0							7.2					0.3	2.6			Tigris R.
96	2H15	21.3-21.4	7.5	11.1	11.1	19.0	22.2	4.3		0.7	2.2	12.2	1.1	0.4		0.3			0.4	2.9		0.3	0.3	0.3		3.6			"older"Tigris R.
96	2H15	22.3-22.4	10.9	27.1	6.2	15.4	11.8	2.3			2.7	9.4	2.3	0.9		0.3	0.3		0.3	8.3	0.3	0.3		0.3	0.3	0.6			"older"Tigris R.
95	2H15	16.1-16.2	13.5	17.3	10.7	22.0	13.8	1.9	0.3			8.8	1.6			0.3				7.2					0.3	2.2			Tigris R.
95	2H15	20.1-20.2	26.1	9.0	9.0	9.0	15.6	3.0		0.3	1.2	9.0	1.5	0.3	0.6	0.3			0.3	10.2			0.3		1.5	2.4		0.3	"older"Tigris R.
84A	2L2	19.7-20.0	11.0	19.0	8.1	19.1	23.9	1.3			1.3	7.1	1.0	1.0		0.3			0.6	3.9	0.3		0.3	0.3		1.6			"older"Tigris R.
85A	2L1	5.4-5.6	50.2	5.1	21.9	9.5	2.7	0.7				0.7				0.3		0.3	0.3	1.0					0.7	2.3	0.3	4.0	foothill
85A	2L1	14.8-15.0	14.9	7.5	8.2	22.8	18.9	2.5		1.1	1.4	9.6	0.3	1.1					1.1	7.1						3.2		0.3	"older"Tigris R.
86A	2L1	19.3-19.5	11.5	7.1	12.0	30.3	16.8	1.9			1.5	7.6		1.2		0.2		0.2	0.7	3.4				0.2	1.0	4.4			pre-Quaternary
87A	2L1	14.8-14.9	57.3	6.8	7.1	13.3	0.6	0.9			0.3	0.6				0.9		0.3	0.9	2.8				0.3	0.3	0.3		7.1	foothill

Table 7. Heavy minerals in the sediments of the Hasmimiya and Badra area

No. of borehole	map sheet	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
73	2D12	15.5-15.6	11.0	7.0	10.6	18.9	25.9	1.7		0.3	1.7	14.6	1.0	0.7		0.3		0.3	0.3	3.7					1.0	0.7			Euphrates R.
73	2D12	23.8-23.9	8.0	19.6	12.2	26.8	12.2	5.1	0.3		0.6	5.6	0.3			0.9			0.6	5.1	0.3	0.6	0.6	0.6		0.6			Mahmudia F.
72	2D12	8.9-9.0	8.3	6.2	10.2	25.2	22.3	3.0		0.3	3.0	13.4	1.6	1.1				0.3	0.3	1.6						3.2			art.canal
72	2D12	17.5-17.6	9.8	13.9	9.0	23.7	15.1	0.9		1.2	1.4	13.6	1.2	1.2	0.3	0.3			0.3	6.4				0.3		1.1	0.3		Euphrates R.
72	2D12	21.4-21.5	13.2	10.4	7.9	25.0	12.6	0.6		0.5	1.1	18.0	2.5	0.3					0.3	5.6					0.3	1.7			Euphrates R.
71	2D12	9.2-9.4	6.7	9.1	6.7	16.3	41.2	1.2		0.9	1.5	8.2	0.6	0.3						0.3					0.2	5.2	1.5		art.canal
74	2D15	6.2-6.4	9.2	6.9	8.7	18.8	30.1	3.6		0.3	0.9	12.8	1.2						0.3	1.8				0.3	0.3	4.2	0.6		art.canal
74	2D15	12.7-12.9	7.8	19.1	19.4	11.3	19.7	2.5		0.3	2.5	10.3	1.6	1.2					0.3	2.2		0.3		0.3		1.2			Euphrates R.
74	2D15	18.4-18.6	9.3	9.0	9.0	28.2	15.8	3.1		0.6	2.8	15.2	1.2	0.3			0.3	0.3	0.6	2.8				0.3	0.3	0.6		0.3	Euphrates R.
75	2D15	17.3-17.5	8.8	14.0	10.0	21.1	13.1	3.1	0.3	0.3	2.0	19.9	1.4	0.8	0.3			0.3	0.3	2.6				0.3		1.4			Euphrates R.
31	2H2	10.1-10.2	15.1	2.3	18.5	16.6	24.9	1.5		0.4	0.4	2.6	0.8						0.4	2.7					0.8	18.5	1.1	2.6	Tigris R.
31	2H2	16.3-16.4	11.8	12.1	16.2	17.5	9.4	3.0		0.7	0.7	15.2	3.0	0.7		0.3	0.3		0.7	6.0	0.3	0.3		0.3		1.3			Tigris R.
30	2H2	19.1-19.3	18.0	16.2	7.2	18.6	12.6	5.4	0.3	0.3	0.6	9.6	1.2		0.3	0.3		0.3	0.6	6.6			0.3	0.3	0.3	1.2			"older"Tigris R.
16	2H5	7.9-8.0	18.6	9.1	6.3	22.1	18.6	0.9			0.6	7.6	1.6						1.3	8.5					0.9	8.8			Tigris R.
17	2H5	23.2-23.4	13.4	8.1	6.8	19.2	24.1	1.6		0.3	2.3	9.4	2.0					0.3	0.7	9.1					0.7	1.3			"older"Tigris R.
62A	2G12	14.9-15.0	16.8	7.2	10.5	21.0	22.3	2.1		0.3	0.3	6.0	0.6	0.3				0.3	0.6	5.4		0.3	0.3			5.7			Tigris R.
60A	2G12	14.0-14.1	19.4	1.2	10.1	6.6	8.9	3.1		0.4		1.9	0.4			0.4				2.3						31.0	13.4	0.8	foothill
60A	2G12	21.0-21.1	14.1	16.6	12.4	26.6	8.6	0.6		0.3	1.1	5.5	0.8		0.3		0.3	0.3	0.6	8.9			0.3	0.5	1.1	0.3	0.3	0.5	"older"Tigris R.
61A	2G12	3.1-3.2	62.4	6.3	4.4	7.5	1.5			0.3					0.6	0.6	0.3	0.9	0.6	3.5					2.2	4.7	0.3	3.8	foothill
61A	2G12	19.4-19.5	73.7	4.3	2.7	7.3		1.7				0.3				0.3		0.3	0.3	0.7					0.3	0.7		7.0	foothill
83	2D16		7.4	9.6	8.9	21.5	26.3	2.6		0.4	1.5	16.7	1.7	0.4					0.4	1.1			0.4		0.4	0.7			art.canal
83	2D16		13.3	12.0	11.0	23.0	17.1	2.3		1.0	1.9	9.7	1.3	0.6				0.3	0.3	3.6						2.6			Euphrates R.
83	2D16		15.6	11.4	8.0	27.5	17.4	1.8		0.3	1.2	8.4	0.9	0.3		0.6				4.8				0.3		1.5			Euphrates R.
84	2D16	3.2-3.4	6.4	5.5	9.4	21.6	31.3	2.2			1.4	15.8	2.2						0.3	1.7						2.2			art.canal
84	2D16	19.3-19.5	6.3	16.4	10.1	32.4	13.0	3.3			2.3	9.7	1.3	0.3		0.3				4.0		0.3	0.3						Euphrates R.
85	2D16	3.2-3.4	5.9	2.2	12.4	15.2	37.5	3.4			1.2	7.1	0.3		0.3			0.3		0.9			0.3			11.8	1.2		art.canal
85	2D16	12.0-12.2	12.9	1.8	11.4	14.2	19.9	1.5			0.3	5.5								0.9						23.6	8.0		art.canal
85	2D16	19.5-20.0	13.1	14.3	9.8	25.6	16.1	3.6		0.3	0.9	9.8	0.9	0.3				0.3	0.3	3.6						0.9			Euphrates R.
91	2H4	9.3-9.6	13.7	9.2	13.1	20.3	20.3	4.6				3.9	0.6			0.6		0.6		0.6						9.2	2.0	1.3	art.canal
91	2H4	20.0-20.5	7.2	16.1	6.6	15.8	15.6	3.7		0.6	2.9	21.3	1.7	0.9		0.3		0.3	0.6	4.6		0.3		0.6	0.6				Euphrates R.

Table 8. Heavy minerals in the sediments of the deep boreholes between Mahmodiya and Mandali

No. of borehole	map sheet	no. of sample	depth (m)	opaque minerals	clouded minerals	rock fragments	zoisite-epidote group	amphibole common	amphibole brownish	glaucophane	tremolite-actinolite	orthopyroxene	augite diops. augite	titanaugite	pyroxene whitish	rutile	zircon	apatite	tourmaline	titanite	garnet	andalusite	sillimanite	kyanite	staurolite	chromite	chlorite	biotite	barite-celestite	origin of sediments
DBH 1	2C8	1	22.1-22.2	13.5	17.0	14.7	20.5	10.1	2.3		0.9	0.9	12.1	2.3	1.2						3.2		0.3	0.3	0.3		0.3			Tig.+Euphr. R.
DBH 1		2	30.9-31.0	13.5	12.6	12.9	28.0	12.3	3.6		0.3	0.3	3.4	0.3	1.1	0.8	0.3		0.3	1.1	7.6	0.3	0.3	0.3	0.3		0.6			res.Mahmudia F.
DBH 1		3	33.9-34.0	13.0	16.4	10.4	20.7	13.8	5.5		1.2	0.9	7.7	1.7	0.9	0.3			0.3		4.3		0.3	0.3	0.3	0.3	1.7			Tig.+Euphr. R.
DBH 1		4	44.6-44.8	16.8	14.7	13.2	22.0	17.7	4.2		0.3	0.3	3.9		0.3				0.3	0.6	0.9	0.3		0.3	0.3		4.2	0.3		res.Mahmudia F.
DBH 1		5	49.6-49.8	14.5	15.4	9.8	19.0	14.8	2.7	0.3	1.2	0.9	5.3	1.5	0.3	0.3	0.3			0.6	9.8	0.3	0.6	0.6	0.3	0.9	0.9			Tig.+Euphr. R.
DBH 1		6	52.8-53.0	9.2	29.1	14.1	16.4	7.2	1.4		1.2	0.3	12.1	1.3	0.3		0.3				4.0	0.9	0.3	0.3	0.9	0.3	0.9			Euphrates R.
DBH 1		7	55.7-55.8	20.3	18.9	7.3	12.7	8.7	1.9	0.2	0.7	1.4	16.3	0.9	1.7	0.2	0.2			0.2	6.6			0.2	0.5	0.2	0.7			"older"Euphr. R.
DBH 1		8	65.9-66.1	14.3	22.8	9.3	24.1	9.8	2.2		0.5	0.3	1.7	0.2	0.5	0.2	0.5		0.2	0.5	10.0	0.2		0.8	1.7	0.2				Mahmudia F.
DBH 1		52	78.7-78.8	17.4	13.3	6.5	23.9	16.5	3.8			0.3	1.8	0.6	0.6	0.3	0.3		0.3	0.6	10.6	0.3			0.3	0.3	2.4			Mahmudia F.
DBH 2	2C12	6	28.1-28.3	16.5	11.0	12.4	18.4	8.5	2.2	0.3	0.8	1.4	17.9	2.5	0.5				0.5	0.3	4.9	0.3	0.3	0.3	0.5	0.5				Tig.+Euphr. R.
DBH 2		7	34.0-31.2	17.4	7.6	12.8	20.2	15.6	2.8		0.3		10.8	1.4	1.0	0.3	0.3			0.3	6.3		0.3	0.3		0.3	1.7			Tigris R.
DBH 2		8	45.3-45.5	16.6	10.9	14.3	21.6	11.4	1.3		0.8	0.3	11.7	1.0	0.5	0.3	0.8		0.3		7.0					0.5	0.8			Tigris R.
DBH 2		9	54.0-54.2	18.6	20.7	13.2	10.7	9.1	1.9		1.1		14.5	1.3	0.8	0.3				0.3	4.8		0.3	0.3	0.3	0.8	1.1			Euphrates R.
DBH 2		10	62.2-62.4	15.7	6.1	18.5	13.4	22.0	2.6		0.6	1.0	6.1	0.3	0.3		0.3		0.6	0.6	6.1	0.3		0.3			5.1	0.3		Mahmudia F.
DBH 2		11	75.0-75.3	12.0	12.0	11.4	22.0	19.9	6.4		0.3	0.8	6.6	0.3	0.8			0.3	0.3	0.3	2.9			0.3	0.3	0.5	2.7			Mahmudia F.
DBH 2		12	86.6-86.8	17.4	12.8	10.9	14.8	20.3	5.3	0.2	0.5		2.9		0.5	0.2			02.	0.5	2.7		0.2	0.2			9.7	0.2		pre-Quaternary
DBH 2		32	95.0-95.1	13.0	15.6	12.4	15.4	15.0	1.7			0.6	9.5	1.2	0.9	0.6	0.3			0.3	9.5					0.3	3.8			pre-Quaternary
DBH 2		49	112.4-112.6	17.8	10.3	13.4	19.8	16.4	4.5			0.3	6.2	1.0	1.4			0.3	0.3	0.3	5.4			0.3			2.1			pre-Quaternary
DBH 4	2C16	16	4.5-4.6	21.6	11.2	5.6	24.4	9.6	3.2			1.6	7.2	10.0	0.4	0.4	0.4				2.8					1.2	0.4			Diyala R.
DBH 4		17	12.9-13.0	8.8	12.3	6.6	19.1	24.8	5.7		2.0	1.1	12.5	2.0		0.3	0.3	0.3			2.8			0.3			1.1			Tig.+Diyala R.
DBH 4		18	18.0-18.1	14.2	12.7	6.2	18.5	20.4	7.6		0.4	0.4	9.1	3.6		0.4	0.4			0.4	4.7				0.4		0.7			"older"Tigris R.
DBH 4		19	25.8-26.0	22.2	20.1	10.4	14.2	9.5	1.5	0.3		1.5	10.7	2.7	0.3						4.7	0.3	0.3				1.5			"older"Tigris R.
DBH 4		20	31.8-32.0	16.9	17.9	7.9	16.0	16.3	3.2			1.3	14.4	1.0	0.3						3.8						1.0			"older"Tigris R.
DBH 4		21	36.8-37.0	18.9	14.6	9.3	21.6	13.6	1.5			0.3	9.6	1.2			0.3				7.2					0.3	1.2			"oldest"Tigris R.
DBH 4		22	41.0-41.2	14.3	11.0	11.9	21.5	18.5	3.3			0.6	4.8				0.3		0.6	0.6	7.8				0.3		4.5			"oldest"Tigris R.
DBH 4		23	47.8-48.0	20.3	21.6	9.5	21.2	8.5	2.3		0.3		7.2	2.0						0.3	4.9	0.3		0.3			1.3			"oldest"Tigris R.
DBH 4		24	51.8-52.0	21.6	31.2	9.3	14.0	9.6	1.3		0.3		2.7	0.3	0.3		0.3			0.3	5.3	0.3		0.4	0.4		2.3			Mahmudia F.
DBH 4		44	65.0-65.2	17.8	39.2	8.6	15.9	3.2	1.0		0.3	0.7	2.3	2.3	0.3	0.3					7.1	0.3	0.3	0.3			0.7			Mahmudia F.
DBH 4		45	66.2-66.3	15.0	24.3	8.6	18.9	10.9	1.9			0.6	6.4	3.8			0.3				7.6			0.3	0.3		0.9			Mahmudia F.
DBH 4		54	69.3-69.5	17.0	13.7	4.3	18.7	18.4	3.0		0.3		9.7	0.3	0.7	0.3	0.3		0.3	0.7	8.4	0.3		0.3	0.3	0.3	2.7			pre-Quaternary
DBH 4		55	73.6-73.7	17.6	22.7	8.6	22.9	8.8	2.9	0.3		0.5	2.1	0.3		0.3	0.3	0.3		0.5	11.2	0.3		0.3	0.3	0.3	0.8			pre-Quaternary

Table 8 (*continued*)

DBH 5	2G3	11	13.0-13.2	13.0	10.6	14.2	21.0	15.7	3.2	0.3	0.3	0.6	5.9	3.0	0.6	0.3	0.3			0.3	7.1					0.3	3.0		0.3	Tigris R.
DBH 5		12	19.0-19.2	18.2	8.8	14.9	26.2	13.4	0.8		0.2	0.3	7.1	2.5			0.2		0.5	0.3	5.3			0.2			0.8			Tigris R.
DBH 5		13	24.0-24.3	12.7	14.7	14.3	27.0	7.3	0.8		1.2	0.4	7.7	2.7	0.4		0.4				7.7	0.8			0.4	0.4	1.2			"older"Tigris R
DBH 5		14	26.0-26.2	19.2	9.0	16.3	15.1	16.0	1.6		0.3	0.6	5.1	3.8	1.0		0.3			0.3	8.0	0.3				0.3	2.9			"older"Tigris R.
DBH 5		15	31.8-32.0	18.2	9.5	18.2	13.5	17.4	2.1		0.8	1.3	5.3	2.4	0.8				0.5		5.3	0.3					4.7	0.3		"older"Tigris R.
DBH 5		16	33.3-33.5	21.4	10.5	9.1	27.6	8.5	1.4		0.3	0.6	4.0	2.3	0.6		0.6	0.3	0.3	0.3	10.6		0.3	0.3	0.3	0.8				"oldest"Tigris R
DBH 5		17	39.4-39.6	13.9	15.7	8.0	26.2	13.6	1.2		0.9		9.4	1.5	0.3		0.3			0.3	6.2			0.3	0.3		1.9			"oldest"Tigris R.
DBH 5		18	45.8-46.0	19.6	22.6	13.0	20.2	9.3	1.5		0.3	0.3	3.3	1.5	0.6					0.3	4.2	0.3					3.0			"oldest"Tigris R.
DBH 5		48	68.6-68.8	23.1	15.3	10.1	15.6	14.2	2.6		0.4	0.4	5.6	1.1	1.1		0.4		0.4		3.0						6.5	0.4		Mahmudia F.
DBH 5		52	75.1-75.2	27.1	15.4	11.7	17.9	6.7	4.2			0.8	5.4	6.3	0.4		0.4				2.5			0.4	0.4		0.4			Mahmudia F.
DBH 5		53	83.0-83.2	21.1	25.0	9.8	16.8	8.6	3.5			0.4	4.7	7.0	0.4		0.4				2.0						0.4			Mahmudia F.
DBH 5		80	93.0-93.2	34.6	16.7	6.6	23.7	3.1	1.9			1.2	1.9	5.1		0.4	0.4			0.4	3.9									Mahmudia F.
DBH 6	2G6	8	21.4-21.5	66.9	4.4	5.1	4.7	1.7	0.5				0.5				0.3			0.3	1.2					0.2	1.0		13.2	foothill
DBH 6		9	25.7-25.8	38.9	10.2	10.9	8.4	2.5	0.4			0.4	0.7			0.3	0.4		0.3	0.4	3.3					1.5	0.7		20.7	foothill
DBH 6		69	49.0-49.2	44.0	11.1	7.0	16.7	1.9	1.2				0.5	0.3				0.2	0.5	0.3	3.6	0.2				1.0	0.5		11.1	foothill
DBH 6		11	56.5-56.6	59.5	3.8	5.9	11.4	1.0	1.4				0.7	0.3			0.3		0.4	2.1	4.5					1.4	1.7		5.5	pre-Quaternary
DBH 6		12	66.4-66.5	60.4	7.1	8.5	11.6	0.9	1.3				0.4	0.4			0.4	0.4		1.3	3.6					0.4	0.4		2.7	pre-Quaternary
DBH 6		13	84.5-84.6	46.1	8.9	5.7	13.8	2.5	0.7	0.4			0.7				0.4		0.4	0.4	4.3			0.3		0.7			12.4	pre-Quaternary
DBH 6		14	88.3-88.4	45.1	8.3	6.9	14.4	2.5	2.2			0.4	1.1		0.4		0.4		0.4	1.1	4.7				1.0	1.4	0.7		10.1	pre-Quaternary
DBH 6		70	128.8-128.9	47.8	8.7	6.2	7.8	1.2	0.3	0.3			0.6				0.3				3.4					0.3	0.3		22.7	pre-Quaternary
DBH 6		71	158.0-158.1	52.3	4.5	5.7	9.7	1.5	0.6		0.3		0.6			0.3			0.3		6.0					0.6	1.5		16.0	pre-Quaternary
DBH 6		72	168.6-168.7	41.8	9.6	6.5	10.7	0.7	0.7	0.3			0.4			0.3			0.4	0.3	5.8					0.7	0.7		21.2	pre-Quaternary
DBH 6		97	189.5-189.6	38.0	9.3	7.1	22.8	0.7	1.2		0.3		0.3				0.5	0.2		0.7	4.7			0.2		0.7	5.7		7.6	pre-Quaternary
DBH 6		100	202.3-202.4	52.2	5.4	10.8	13.4	2.6	1.0	0.3						0.6	0.3	0.3	0.3	0.6	2.5					1.0	2.2		6.4	pre-Quaternary