MINERAL FACIES INVESTIGATIONS IN THE
ALGYŐ-AREA

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SUMMARY

In the major part of the Algyő-area and in the southern part of the Danube—Tisza Interfluve the overwhelming majority of the basement complex under the Pannonian sediments is constituted by Variscian metamorphites of simple mineral composition in general. In the Algyő-area a sediment series of 2600 to 2800 metres thickness had developed during the Pliocene and Pleistocene periods. The temperature and pressure conditions reached only the thermal and pressure values of the methydric zone while they did not reach those of the diagenetic zone. This fact is proved by the existing mineral paragenesis. On the basis of the data calculated from the chemical composition of the Lower Pannonian basal conglomerates, sandstones and aleurites sampled from different depths, the *ACF* and *A'KF* triangular diagrams were drawn. On the basis of the projection points got in such a way the picture of the green schist facies of lower temperature became distinct and which contained quartz, albite, muscovite, biotite and chlorite as critical mineral and on this basis it is similar to the paragenesis of the *Abukuma-type*. In the *AFM* diagram chlorite covered nearly the same projection area than that of the literature data, while in case of biotite it is obvious that the members of this area are richer in Mg. The Lower Pannonian sediment series of several hundred metres thickness lying on the basement complex is the substance of the erosion area of nearly the same structure where, after deposition of the basal conglomerate, erosion of W-E direction is to be taken into consideration.

INTRODUCTION

In the axis of the hydrocarbon occurrence of the Szeged environs (Algyő) a buried metamorphic block range extends nearly in NW-SE direction. Its substances are metamorphites formed by Variscian metamorphism from older formations, i. e. mica schist with chlorite schist intercalations, quartzite, garnetiferous mica schist, gneiss and amphibolite. According to the data received so far in the position of the metamorphites certain zonality can be observed. These rocks determine for the most part the petrological structure of the so-called „basal conglomerate level" of Lower Pannonian age lying on the basement complex, and the mineral composition of the Lower Pannonian formations lying above them, to a certain extent. In the western side of the Algyő-structure and in the eastern part of the Deszk-area there occur such formations lying on the basement complex, which on the basis partly of their formations and partly of their fossils belong to the Upper Tortonian [BALOGH, 1968]. Therefore in the course of redeposition these detrital formations are to be taken into consideration to a certain extent.

CHARACTERISTICS OF THE LOWER PANNONIAN SEDIMENTS

In greater part of the Algyő-area there occur Lower Pannonian sediments of 400 to 600 metres thickness lying partly on the basement complex and partly on Upper Tortonian sediments. The lowermost member of this series is the „basal

conglomerate". This is not wide-spread, it is absent in the higher parts of the base-
ment complex and is eroded from this place and wedges in the margins. The basal
conglomerate level is, therefore, of varied thickness. This is not really a conglomerate
which is proved by the facts that the grain-size over 2 mm diameter is of insignifi-
cant quantity, moreover, the coarse sand fraction (0.5 to 2.0 mm) hardly reaches
one or two per cent. The measure of roundness is also very different. According to
BÉRCZI [1970] the formation has to be regarded as lithoarenite. The basal conglo-
merate is composed of quartzite, mica schist, chlorite schist and of detritus of gneiss
and amphibolite. As a result of this the quartz of undulatory extinction is frequent
and which contains sometimes oriented inclusion series and in which twin of com-
pression formed *(Fig. 1)*. Out of the microcline, orthoclase, plagioclase of dense
twin-strips, muscovite, biotite and chlorite frequently of rutile inclusions can be
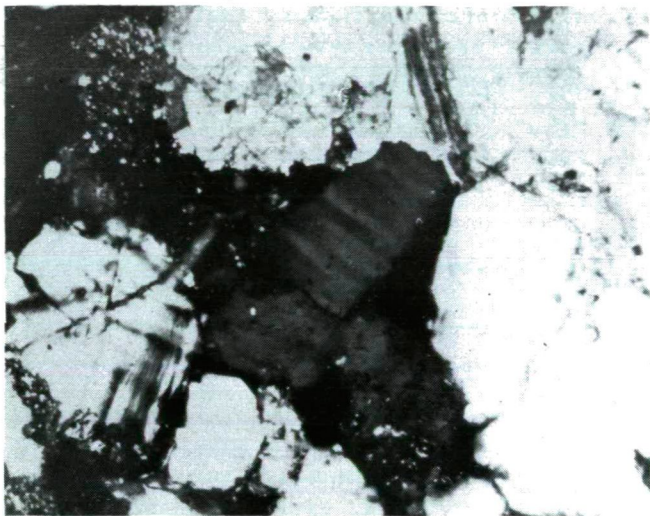found. In the pelitic substance kaolinite and illite occur out of the clay minerals.

Fig. 1. Compression twin in quartz

The detritus of weathering coat being in the lower level, relates to the fact that
first the decay cover redeposited and the erosion of the compact metamorphite
followed this process. This process took place within a relatively short time, its det-
ritus is assorted only to a small extent and assortment of certain size occurs in the
uppermost part of this level, at most.

Above the Lower Pannonian basal conglomerate there is a grey, compact lime-
marl level with varied transition zone. The sediment consisting of mainly chemical
sediments is a calm-pelagic sediment series, which originated in a basin deepened some-
times under reductive conditions [BALOGH, 1969]. According to the X-ray diffrac-
tometric data of the insoluble residue of the rock treated by $2N$ hydrochloric acid it
contains kaolinite, chlorite, muscovite, quartz and goethite. Due to the small grain-
-size rock-forming minerals could not be determined under microscope.

In the above-lying marly, clay-marly and sandstone-containing formation series
fine-grained sandstones can be found which are reservoir-rocks of hydrocarbons.

The predominant grain-size is 0,1 to 0,2 mm which fact relates to rather good assortment. The bulk of the grains is quartz in several cases being of undulatory extinction. The rather frequent inclusion bands lie sometimes parallel with the rhombohedron planes, and are ordered sometimes parallel with the planes of the principal resp., secondary axes; in some grains compression twins also occur. Out of the feldspars orthoclase, microcline and plagioclase of polysynthetic twinning can be found. The quantity of feldspars is considerably less than that of the micas. The chlorite is of changing quantity, its quantity increases downwards, moreover, it can surpass the quantity of micas. The garnet, amphibole, zircon and apatite play insigni-
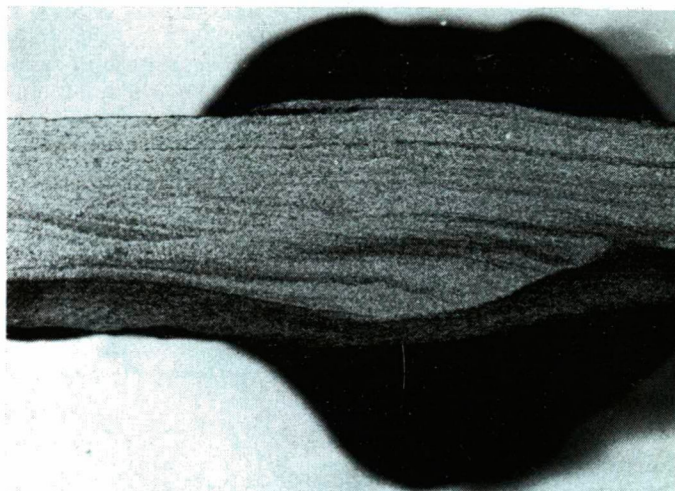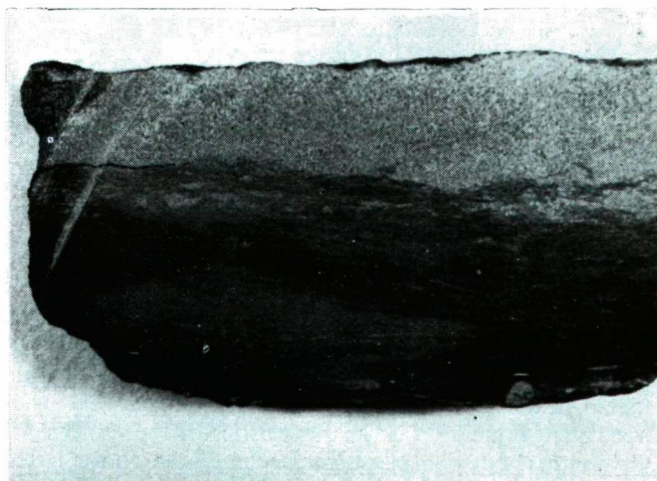

Fig. 2. Ripple mark in fine-grained sand

Fig. 3. Wedging aleurite in sandstone

ficant role, the two latter ones can be found mainly in form of inclusions. The cementing substance is carbonate which is calcite in the basal conglomerate level and calcite or dolomite in the layers above it.

The sandstones form thinner intercalations in the aleurite. These may show different textural and structural forms which may relate to their genetic conditions. In the fine-grained sandstone the buried ripple marks and cross-bedding *(Fig. 2)*, and in sandstone the wedging aleurite grains *(Fig. 3)* are frequent phenomena. In other cases fine-grained sandy strips are interbedded into aleurites *(Fig. 4)* but the sandstone and marl may also sharply be separated *(Fig. 5)*. In microscopic measures the desiccated hydrocarbons may cause micro-laminations *(Fig. 6)*. Coalificated plant remnants may cause band-forms, moreover, micas may abound also in strip.

The aleuritic parts of the formation relate to the deposition in calm water while sand intercalations indicate streaming water. In the Lower Pannonian strata these two factors play significant role in developing the different facies formations.
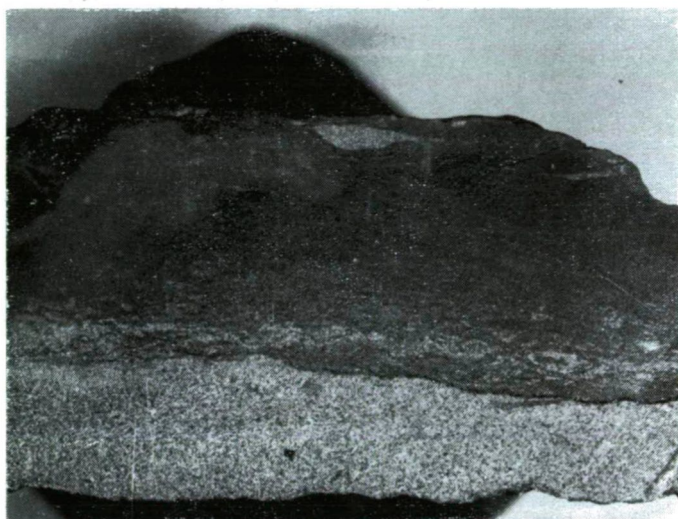

Fig. 4. Fine-grained sandy strips in aleurite

PRESSURE AND TEMPERATURE CONDITIONS IN THE LOWER PANNONIAN STRATA

According to the investigations during the Pliocene and Pleistocene periods sediments of 2.600 to 2.800 metres thickness originated in this area. The question is raised whether in this region such lithostatic pressure could exist, in the course of which, over the diagenesis, the metamorphism could begin or the anchimetamorphic zone could develop at least. The other question is that whether it would be possible to recognize some kind of characteristics of the mineral facies from the chemical composition of the detrital substance accumulated on the basement complex and whether any conclusion concerning the mineralogical-petrological facies conditions of the original rock could be drawn. This detrital substance derived either

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directly from the basement complex or its detritus was several times transported and redeposited.

It is easy to answer first question. While in the Lower Pannonian sediments only the metamorphism connected to the subsidence took place, the thermal and pressure conditions as well as the critical minerals belonging to such metamorphism, are to be investigated.
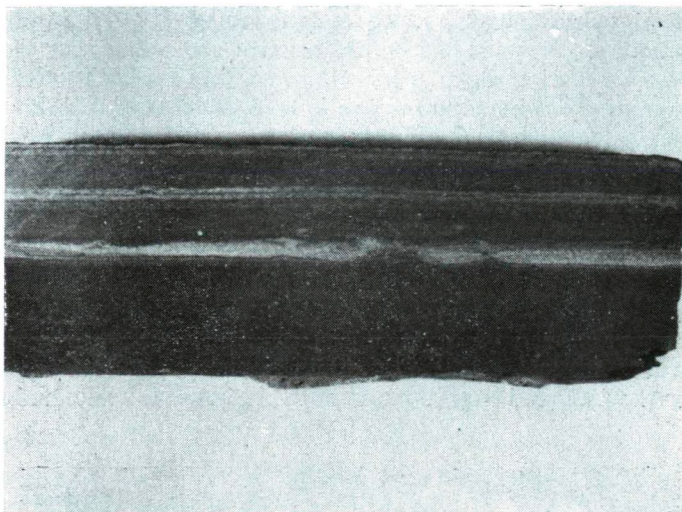

Fig. 5. Separation of sandstone and marl

According to the data of DANK [1965] and SOMFAI [1970] in the Lower Pannonian sediments of Algyő the pressure gives such values that overpressure is to be taken into consideration only in the level of basal conglomerate. This value is of about 25 per cent. The temperature values of these formations change between 90 to 156 centigrades depending first of all on the depth.

The Lower Pannonian sediments of Algyő lie in a depth of 2.000 metres in general, so they surpassed the pressure and temperature characteristics of the met-hydric zone. The diagenetic zone of deeper position corresponds to the position of the local sediments and the values of temperature do not exceed, too, the upper limit characteristic of this zone. As a result of this there is no clay mineral transformation. According to the investigations kaolinite and montmorillonite transform gradually into illite in the laumontite-prehnite facies. While kaolinite exists in the basal conglomerate level therefore no anchimetamorphic zone is probable. Temperature is also not high enough because the transformation of the clay minerals takes place at about 350 to 400° C and in consequence of this the lower limit of the facies may be put at this temperature value. The absence of the anchimetamorphic conditions is also proved by the fact that laumontite, prehnite as well as the secondary chlorite, albite and calcite are absent.

Finally it can be stated that in the Algyő-area the minerals of the Lower Pannonian strata proved to be the broken fragments of the original rock; and in the

course of subsidence no conditions could form under which the critical minerals could develop. This relates to the fact that the stability of the original minerals remained under the conditions mentioned above.

EVALUATION OF THE CHEMICAL ANALYSES (ACF, A'KF AND AFM DIAGRAMS)

In addition to microscopic, X-ray, DTA and TG investigations the chemical analyses were also used to determine the mineral facies, namely whether it would be possible to draw any conclusion concerning the mineral facies of the erosion area from the data of chemical analyses of the typical samples. The samples of the basal conglomerate level of different deep-borings and the aleurite and sandstone samples originating from the strata above it were used in selection of the samples instead of the classification of the Lower Pannonian published by KÖRÖSSY [1968].

It is well-known that the graphical demonstration of the minerals occurring in one facies is possible only in that case when the number of components determining the mineral's composition is not greater than the suitable numbers for geometrical demonstration. In the recently used triangular diagram of ESKOLA only three components can be taken into consideration. The only condition is that SiO_2 must give a surplus so its quantity should be negligible in the course of calculation. Our samples represent this case. The quantity of CO_2 was also neglected because it can be calculated informingly from the DTA and TG curves. These values may be assigned to the CaO and MgO content of calcite resp. dolomite and determining

Fig. 6. Desiccated hydrocarbon residue in sandstone

the CaO and MgO content bound by carbonates and subtracting this value from the original quantity of CaO and MgO, the remaining CaO and MgO quantities may be practically only in silicate bond. Magnetite and hematite were either absent or were represented only by insignificant quantities. Limonite, however, appeared several times in form of small globules and sometimes pyrite was found. When their quantity was measurable, corrections were applied. When garnet reached measu-

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rable quantity correction was also used. In these cases the value of CaO was pro-portionally decreased in calculating the A'-value. Finally in addition to the alkalies the values of mole numbers calculated from the percentage of the weight of Al_2O_3, Fe_2O_3, FeO, MgO, MnO and CaO, were used.

While Al^{3+} and Fe^{3+} may replace isomorphously each other, therefore these values were summarized in the A-component and the quantity of alkalies was sub-tracted from it. Consequently, this value represents the Al_2O_3-quantity which is not bound to the feldspars. Though muscovite and biotite also contain a small
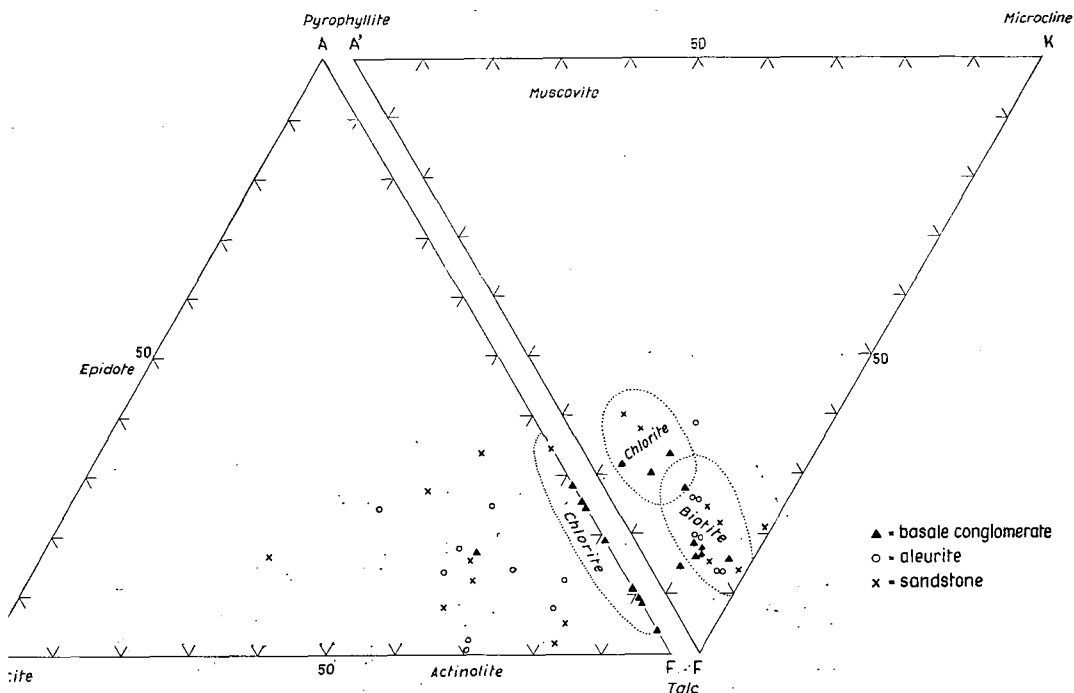

Fig. 7. Projection points, calculated from chemical analyses in the ACF and $A'KF$ diagrams

quantity of H_2O, in our case this neglect of correction does not cause considerable error. The C value represents the quantity of CaO bound to silicates. While apatite is of insignificant quantity, it occurs sometimes in forms of inclusions, therefore the quantity of CaO connected to P_2O_5 can also be neglected. Finally, the F value rep-resents the total quantity of $FeO + MnO + MgO$ bound to silicates.

The $A'KF$ triangular diagram gives useful supplement to the ACF triangle. In this diagram the quantity and quality of the potassium-rich minerals is conspi-cuous. It is a common fact that this expresses also a mole-number relation and the correction of the accessory minerals is to be done as well. A' contains the Al_2O_3 quantity which is not bound to feldspars and the corresponding correction concern-ing the Ca-containing silicates (garnet, amphibole, epidote, etc.) is to be done. In our case only garnet occurs in several times. The K value corresponds to the mole-

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cule number of K_2O and F, in comparison with the foregoing cases, indicates the total value of the molecule numbers of $FeO + MnO + MgO$.

Taking these facts into consideration the position of the single projection points deriving from the analytical data of the corresponding rock samples can be seen in *Fig. 7*.

From the *ACF* diagram it can be stated that projection points, deriving from the basal conglomerate level of different deep-borings, cover satisfactorily the place of chlorites in the *A—F* side. The projection points of the samples deriving from higher levels show certain deviations and this statement is true mainly of the sandstones. As a result of this the conclusion may be drawn that in the course of transportation the minerals being characteristic of the basal conglomerate became "diluted" to a certain extent and were mixed with other minerals. The fact can also be stated that in the neighbourhood of the projection points of the pyrophyllite, epidote and calcite the projection points are absolutely absent. In the samples investigated these minerals could be detected neither by microscopic nor by X-ray investigations, neither in the basal conglomerate level nor in the strata above it.
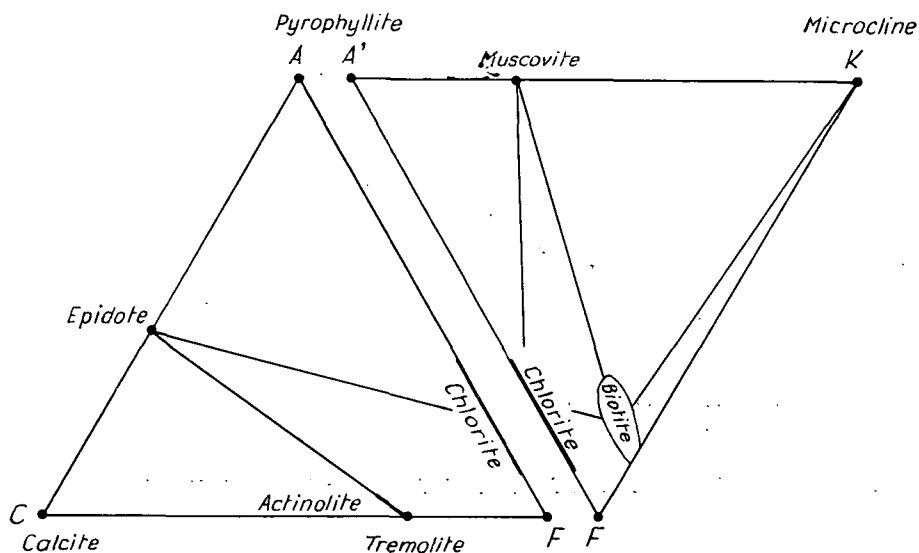

Fig. 8. *ACF* and *A'KF* diagrams of the greenschist facies of Abukuma type

The *A'KF* diagram demonstrates excellently the predominating role of biotite and chlorite. Independently of the depth and rock type (basal conglomerate, aleurite, sandstone) no greater deviations can be found; therefore the same conclusion can be drawn, i. e. that the sediment derives from an area of nearly the same geological structure. The only difference is that the ratio of the minerals to one another changes to smaller or greater extent but the same variety remains. If there would be any deviation this may be concerned to the sandstones of the higher levels.

When comparing the *ACF* and *A'KF* triangle diagrams of the green schist

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facies to those of ESKOLA's plotting it is obvious that there is great conformity with the projection areas derived from the chemical data of the Algyő samples *(Fig. 8)*. Im the *ACF* diagram the projection area of chlorites show a good conformity and in the *A'KF* diagram, however, the projection areas of biotite and chlorite nearly cover each other.

In the *ACF* and *A'KF* diagram the projection points are in keeping with the paragenesis of the *Abukuma type*. This type represents a regionally developed series which formed under relatively low pressure. The temperature is about 700° C, *i. e.* it is a more heated part of the crust and the formation could take place in a depth of 8 to 11 kilometres. In case of this metamorphic series a green schist facies of lower temperature and an amphibolite facies endured larger-scale metamorphism, can be distinguished. In the subfacies of the green schist facies the typomorphic minerals are the quartz-albite-muscovite-biotite-chlorite and quartz-albite-biotite, respectively. The boundary of the green schist and amphibolite facies is represented by the disappearance of chlorite and by the appearance of new minerals, i. e. diopside, grossularite/andradite and staurolite. The typomorphic minerals of the green schist facies relate to the fact that in the overwhelming majority of the basement complex the metamorphism did not get an equilibrial stage in contrary to the metamorphites of the other regions of the Great Hungarian Plain [SZEPESHÁZI, 1968, SZÁDECZKY-KARDOSS *et al.* 1969].

Taking into consideration the possibilities of the *Barrow series* (which can be characterized by a paragenesis representing higher pressure values) it can be stated that the appearance of chlorite is only accidental while it is characteristic of the Algyő-area. The absence of cordierite, kyanite and staurolite relates at the same time to the fact that any green schist type of this series is investigated, it cannot be identified with that of the Algyő-area. Further, the amphibolite facies also could not form and this is proved either by the typomorphic minerals of the *Barrow* or by those of the *Abukuma type*. The absence of the stilpnomelane and epidote in the typomorphic minerals excludes the possibility of existence of the green schist facies of *Barrow type*.

In the *ACF* and *A'KF* diagrams the component *F* contains the quantity of $FeO(MnO) + MgO$. Though FeO and MgO may replace each other isomorphously, the measure of replacement may be different in the FeO- and MgO-containing silicates occurring in the rocks. Among others this measure depends on the chemism of the magma and associated rock as well as on the pressure and temperature. Theoretically FeO and MgO are two independent components of the system and could not be replaced by each other. The *AFM* diagram was developed by THOMPSON [1957] where *A* denotes Al_2O_3, *F* is the FeO and *M* is the MgO.

In the *AFM* diagram it is possible to plot a paragenesis depending on the chemism which developed from pelitic sediments as a result of metamorphism. In this case the metamorphite always contains quartz except several examples. Due to the high silification degree the plotting of those may be neglected. The plotting of H_2O is also negligible in those cases in which the pelitic sediments were metamorphized, for example in case of the basement complex of the Algyő-environs.

The pelitic sediments and their metamorphites can be characterized by the system of nearly SiO_2—Al_2O_3—MgO—FeO—K_2O—H_2O composition, when TiO_2 and Fe_2O_3 are bound mainly to biotite, Na_2O to alkaline feldspar and CaO to plagioclase and almandine, respectively. While on the basis of the afore-mentioned facts the quantities of SiO_2 and H_2O are negligible, the number of components of a quartz-contain-

ing metamorphite decreases to four components: Al_2O_3, MgO, FeO, K_2O. As a result of this the composition can be demonstrated in a tetrahedron. From the plotting point of view it is advantageous to investigate the side of the tetrahedron on which Al_2O_3, FeO and MgO are plotted. In this side the K_2O-less minerals, i. e. chlorite, chloritoide, pyrophyllite, the Al_2SiO_5 varieties as well as staurolite, almandine and cordierite can be found. The K_2O-containing minerals, i. e. biotite and stilpnomelane are in the tetrahedron and their projection points are outside the tetrahedron, on the lengthening of the plane. The position of the projection points can be derived from the molecule number calculated from the percentage of weight, on the basis of the following formula:

$$A = \frac{Al_2O_3 - 3K_2O}{Al_2O_3 - 3K_2O + MgO + FeO} \text{ and } M = \frac{MgO}{MgO + FeO}$$

Fig. 9 shows the position of the projection points resulted from these formulae. It is obvious from the results that biotite originating from the metamorphite of Algyő deviates from the literature's data in average value MgO/(MgO + FeO), which is 0,6, in our case it falls between 0,6 to 0,8 and first of all the samples of the
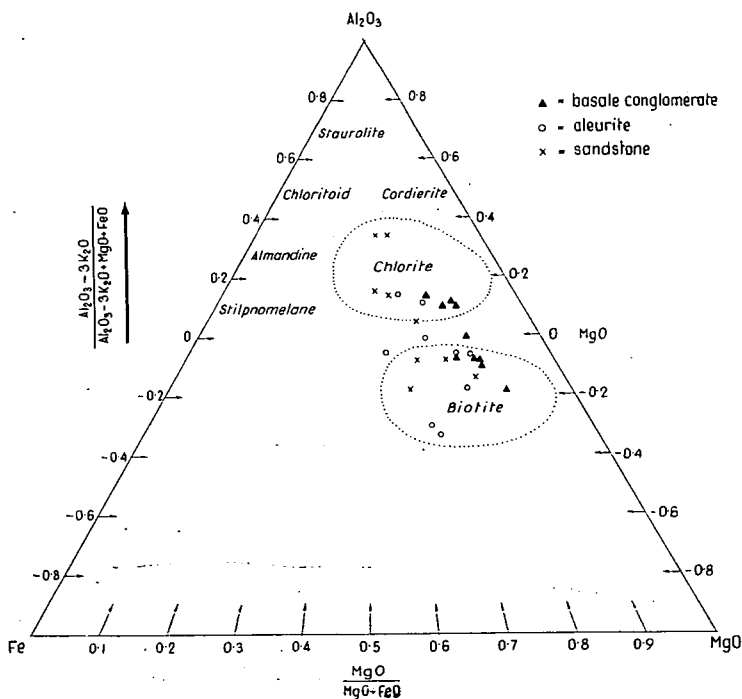

Fig. 9. Projection points calculated from analyses in the *AFM* diagram.

basal conglomerate level are poorer in MgO. The projection points of the chlorites originating from the same samples agree excellently with the values of literature data. From the diagram it is obvious, however, that the substance of the erosion area

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of nearly the same structure accumulated in the investigated series of 200 to 300 metres depth. In the paragenesis, of course, quartz and chlorite occur in addition to biotite and muscovite which is also proved by the facts mentioned above.

PALEOGEOGRAPHIC CONDITIONS

At the end of the Paleozoic era the surroundings of Szeged and the Danube--Tisza Interfluve had been an uplifting and strongly eroding continent for a long time. The products of erosion got the farther-lying sedimentary basins hence the younger sediments deposited on the basement consisting of old metamorphic rocks, in general [SZEPESHÁZI, 1968]. The overwhelming majority of the basement is an unbalanced metamorphite of simple mineral composition, in general. SZÁDECZKY--KARDOSS et al. [1969] related to the fact that in the Szeged-environs there are greenschist and chlorite-schist, respectively. On the basis of the investigations of the absolute geochronology in this area predominantly epi-mesozonal Variscian metamorphism, while in the farther-lying areas retrogressive Alpine metamorphism (chloritization of biotite, sericitization of feldspars) can be observed. According to JUHÁSZ [1969] the overwhelming majority of the metamorphites of the basement complex in the Danube-Tisza Interfluve is a paragenesis which did not reach the equilibrial stage.

In the history of evolution of the sedimentary basins KÖRÖSSY [1970] distinguishes two great sedimentation cycles in the Neogene basins. The first cycle is the Burdigalian-Helvetian marine cycle in the Miocene, the second is the cycle during the Pliocene which may be assigned to the Lower Pannonian. The two cycles are separated from each other by the pre-Pontian erosion in the Sarmatian and Lower Pannonian [SZÁDECZKY-KARDOSS, 1938]. Since the Neogene the stabilized basin floor has moved only vertically and began to subside in the Pliocene. The measure of this subsidence locally surpasses the 3.000 metres [KÖRÖSSY, 1963].

Taking into consideration the position of the Upper Tortonian formations of the Algyő-area it is to be supposed that if the metamorphic range emerged from the sea it did not reach greater heights. This may explain the appearance of the Miocene formations east of Deszk. In this case after the transgression of the Upper Tortonian and before or during that of the Lower Pannonian there ought to be an uplifting surface and this phenomenon may explain the absence both of the Upper Tortonian and the basal conglomerate on the tops of the basement complex. This presumption may also be explained by the observation that lower products of the lower basal conglomerate level are metamorphites of weathering coat and this means the redeposition of the covering strata. The direction of origin of the transgressive sediment cannot be unambiguously determined. The S—N erosion direction is presumable but it had to change within a short time. The NW—SE direction is also probable; this may be proved by the fact that due to the higher chlorite content of the more sandy part of the slightly assorted sediment, accumulated in consequence of the rapid erosion, is of greenish-grey colour in the deep-boring of A-50, 52, 55 and 91. This fact grants the presumption that in the deep-borings of A-71 and 89, lying northwestwards from these in a higher level, the substance of the basement complex is albitic chlorite-schist which had been eroded and could cause the greater quantity of chlorite.

After deposition of the transgressive conglomerate the erosion of WNW direction is more probable. In this direction the mineral composition of the rocks

of the basement complex is similar to that of the sandstones and aleurites above the basal conglomerate. This may also be proved by the fact in the half part of the core of the deep-boring No. 107 *Foraminifera sp.* occurs. Hence it is absent in the Lower Pannonian, it could be redeposited only from the Miocene sediments of the Ásotthalom-environs of higher position (it is plotted in this form also on the map of KÖRÖSSY, 1970). In this deep-boring the above-mentioned core part is in a height of 480 metres above the basement complex, therefore it could not derive from the area of the Deszk-environs but only from the West. There was also considerable relief difference between the Algyő-area and the western part.

Finally it can be stated that after the deposition of the Lower Pannonian transgressive basal conglomerate the Algyő area subsided gradually. The transportation of the clastic sediment was directed into this basin from the west and this process continued during a longer space of time. These are the reasons while the relatively thick sediments of nearly the same character accumulated in this area.

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