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Příspěvky k poznání některých nových nálezů rutilu a ilmenitu

Some Observations on New Finds of Rutile and Ilmenite

(Došlo 14. VI. 1960 presented)

Předložená práce ukazuje výsledky mikroskopického, chalkografického, spektrografického a roentgenometrického výzkumu některých nových nálezů rutilu a ilmenitu s rutilem z oblasti českých krajů.

Nové nálezy r u t i l u byly učiněny v horninách provázejících amfibolity na Lazurovém vrchu u Michalových Hor, jjv. od Mariánských Lázní a v okolí Podmok, jjv. od Čáslavi. Rutily z těchto nalezišť nejsou krystalonomicky omezeny a jsou postiženy silnou resorpcí. Jsou černé až černohnědé se silným polokovovým až kovovým leskem a zřídka patrnou štěpností podle (110).

Zajímavé výsledky poskytl výzkum i l m e n i t ů a i l m e n i t ů s r u t i l o v ý m j á d r e m.

Ilmenit z Cyrilova, ssv. od Velkého Meziříčí, vyskytuje se ve větších smolně černých zrnech nebo agregátech laločnatých zrn v granátickém amfibolitu krystalinika Českomoravské vysočiny. Ilmenit z Moravan, jv. od Čáslavi, tvoří deskovité černé krystaly v hrubozrnných partiích tvořených převážně bytownitem v černozelené facii gabbrového ostrůvku v ortorule běstvinského masivu. Vznikl nepochybně v pneumatolytické fázi.

Zajímavou vnitřní stavbu prozradil mikroskopický a chalkografický výzkum valounků černého ilmenitu s rutilovým jádrem z náplavů Blanice a Otavy u Putimi, jjz. od Písku, a z náplavů potoka Selné u Bražné, vjv. od Kamýka nad Vltavou. Tyto nerosty byly dříve pokládány buď za rutil (nigrin) nebo za ilmenit. Tvoří 2—4 cm veliké, zpravidla jednosměrně protažené valounky barvy černé s polokovovým, na čerstvých plochách i kovovým leskem a černošedým vrypem. Jsou pouze velmi slabě magnetické. Mikroskopicky bylo zjištěno rutilové jádro, obklopené silnou kůrou ilmenitu, který vysílá do jádra prstovité štíhlé výběžky, sledující směry trhlin prismatické štěpnosti podle (100). Ilmenit je zpravidla vždy převládající složkou valounku. Rutilové jádro obsahuje dosti hojné jehlice

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sagenitu, jemné i hrubší dvojčatné lamely podle (101) a nárůstkové zóny. Sytá žlutohnědá barva rutilového jádra je působena jemnými šupinkami hematitu, který byl původně v rutilu rozpuštěn; později došlo za snížené teploty k jeho vyloučení. Podél hrubých trhlin nastává odnesení hematitového pigmentu a tím dochází k „odbarvení" rutilu. Místy je patrna i hydratace hematitu. Vedle toho však tvoří velmi jemnozrnný hematit dosti hojné žilky v ilmenitovém okraji, které jsou rovnoběžné s vertikálou rutilového jádra. Porovnáním této stavby valounků s analogickými nálezy z Malonic, jjv. od Klatov, z Nekvasovů, v. od Klatov a z Jizerské louky v Krkonoších bylo zjištěno, že i zde je patrna buď stavba zcela shodná s výše uvedenými, nebo alespoň velmi podobná.

K ověření stavu rutilu v primárních horninách byl studován výskyt rutilu v amfibolické facii pyroxenicko-granátického rohovce od Hutí, sv. od Bechyně. Také zde možno pozorovat silnou resorpci rutilových zrn a soustřeďování ilmenitu při jejich okraji. Podle toho je možno usuzovat, že koncentrace ilmenitu kolem rutilu v matečných horninách může být obecným zjevem. Ostré hranice mezi ilmenitem a rutilem odporují názoru A. Lasaulxe o přeměně rutilu v ilmenit, neboť pozvolný přechod jednoho nerostu v druhý nebyl zde nikde pozorován.

Po stránce genetické byl zjištěn u všech nových výskytů rutilu i ilmenitu s rutilem jejich přímý nebo nepřímý vztah k amfibolickým horninám, i když pro některé z nich možno předpokládat jako primární naleziště také pegmatity nebo basické diferenciáty granodioritového magmatu.

Souhrnná diskuse provedených spektrálních analys ukázala podstatný rozdíl mezi složením rutilů a ilmenitů s rutilovým jádrem. Nové nálezy ilmenitů s rutilem mají velice sblížené chemické složení, neliší se však podstatněji od složení ilmenitů z jeho známých zahraničních nalezišť.

Some Observations on New Finds of Rutile and Ilmenite

The present paper represents a revision of some specimens of rutile and ilmenite belonging to the collection of the Department of Mineralogy of the National Museum in Prague for some time past but it also contains the results of investigation of some newly obtained specimens. None of the specimens of rutile and ilmenite treated here have yet been described in the literature; at the most, in individual cases, they have been registered without detailed description and exact identification.

A. Two new finds of rutile

Rutile from the Lazurový vrch near Michalovy Hory

The new find of rutile originates from an old deserted limestone quarry on the NNE slope of the Lazurový vrch (formerly Lasurberg, alt. 654 m), situated NNW of Michalovy Hory, SSE of Mariánské Lázně (inv.

no. 42 496; Dr. J. Hrbek, July 18, 1958, legit). The quarry was opened in a powerful inlay of multicoloured crystalline limestone in amphibolites, which form the well-known triangular massif between Bochov near Karlovy Vary, Kynžvart and Planá near Mariánské Lázně. F. Hochstetter (10, p. 804), in his report on detailed geological mapping of the region mentions mostly epidote (pistacite) as occurring on the Lazurový vrch, either as epidotic (pistacitic) schist or as crystals in cracks. Epidotic schist alternates here repeatedly with amphibolites.

The specimen obtained exemplifies the transition from very fine-grained amphibolite to light yellow-green epidote facies, the two parts being connected by a very fine-grained light-grey limestone. In the centre of this ore-vein section, a black-brown, somewhat elongated rutile grain with semimetallic lustre about the size of 11 × 6 mm, with light-yellow to brown-yellow streak. It is completely surrounded with limestone with an admixture of epidote and it is provided with a light-yellow border along its circumference.

The thin section revealed only a part of rutile grain (4.0 × 5.1 mm in size) of light-brown colour, embedded in a fine-grained mixture with predominating calcite which forms, at places, continuous, somewhat more coarsely granular veinlets. In addition to calcite, the specimen contains grains of epidote of about the same size which are strikingly light yellow-green; at a greater distance from the centre of the thin section amphibole is more abundant. Only rarely do we find ore grains which appear black with a marked bluish tinge in reflected light. Since the rock specimen affects the position of magnetic needle, we may be dealing here with magnetite or possibly ilmenite.

The bounding of the rutile grain is irregular, only its unidirectional elongation being marked. Crystal faces are not apparent anywhere in the specimen and the mineral surface is markedly rounded and corrugated by resorption which may also account for the relatively deep channels which are penetrated by both epidote and calcite with ilmenite (magnetite). Cleavage could not be demonstrated unequivocally in the thin section since we are dealing here mostly with irregular fissures formed most likely by pressure. Only some rectilinear cracks could be taken for fissures of prismatic cleavage. Pleochroism could not be observed. The rutile has its usual high relief and marked birefringence which is obliterated by the rich colour of the mineral. Ore grains from the vicinity accumulate near the surface which may be due to the material relationship between rutile and magnetite or ilmenite.

Genetically, the rutile can be considered here as a typical product of metamorphism, formed by a transformation of the original minerals containing Ti. Its imperfect shape is most likely due to its irregular development during metamorphic processes as well as to the surrounding. The relatively small amount of material did not permit of a more detailed investigation of the mineral to be made. Roentgenometric analysis was carried out by the powder method of Debye and Scherrer using an apparatus made by Chirana (Mikrometa) under the following conditions: chamber diameter 57 mm, radiation $CoK_{\alpha\,1,2}$, $\lambda = 1.785$ kX, filter Fe, voltage 30 kV, intensity 15 mA, exposure 180 min., film Agfa Laue. After measurement a correction was allowed for the shift of lines due to absorption. The values obtained are shown in the Table 2. in comparison with the hitherto known *d* values for rutile. The values for rutile are in good agreement with those for rutile from other localities. On comparing them with values for ilmenorutile from the Ilmen Mts. in Ural it may be seen quite clearly that the specimen from the Lazurový vrch resembles in its *d* values more pure rutile than ilmenorutile. On comparing with *d* values of ilmenite, rather marked deviations were observed. Some relatively small deviations in lines can be accounted for by the microscopically demonstrated admixture of fine grains of magnetite or ilmenite.

Rutile from Podmoky near Čáslav

The mineral specimen described by the donor as ilmenite (inv. no. 34 799, Č. Růžička, Čáslav, June 7, 1942, legit) was found in the amphibolite island in the gneisses of the wider vicinity of Čáslav. It was collected in the well-known quarry Mastná bába in the wood W of Římovice, WSW of Golčův Jeníkov, SSE of Čáslav. J. V t ě l e n s k ý (39, p. 40) was correct in pointing out the considerable percentage of Ti in this part of amphibolites which is displayed by the relative abundance of titanium minerals. He describes from the above locality imperfectly bounded crystals of blood-red to yellow-brown rutile as much as 12 cm in size, several cm large crystals of ilmenite with a titanite border and finally titanite itself in damaged yellowish and yellowish-brown crystals, 5 cm in size, with enclosed ilmenite. According to Č. R ů ž i č k a's information published by J. K r a t o c h v í l (21, p. 33—34) rutile from this locality passes over to a dark-red and completely black colour thus forming ilmenorutile. J. K o n t a (16, p. 6) described titanite from the surrounding limestones, in its vicinity some small amounts of nigrine being found. Most recently, the occurrence of rutile in this locality was taken up by J. N o v á k (27). The above facts necessitated a revision of the specimen obtained for the purpose of correct identification.

According to the description of Č. Růžička the mineral in question resembles most ilmenorutile but the finder designated it as ilmenite which was justified on macroscopic investigation by its red-brown translucence along the edges. The specimen is taken from dark-green amphibolite with abundant light-grey veinlets of fine-grained albite as much as 5 cm in thickness, occasionally with an admixture of grey-green chlorite, finegrained clusters of yellow-green epidote and rarely also with minute clusters of granular pyrite. It was in these very veinlets that markedly large crystals of the mineral investigated were found. They are at first sight well defined by their marked metallic lustre, dark colour and large, unidirectionally elongated forms (Tab. XXXVI.a). The largest individual attains the size of 6 × 2 cm. In common with the previous locality, no traces of crystalonomic bounding can be found here; all individuals are markedly rounded by surface resorption. One among them is markedly knee-shaped which indicates the well-known twinny intergrowth. Only at some places cracks of perfect cleavage along (110) can be observed, but mostly only an uneven fracture may be seen. All the individuals observed possess signs of marked influence of great pressure. They are black to black-grey, in fine fragments they display yellow-brown translucence, streak is yellow to yellow-brown.

The powder preparation exhibits on larger fragments blackbluish colour in reflected light while finer fragments are dark yellow-greenish in transmitted light. This very colour is very characteristic for many of the known rutile occurrences. In some fragments rather marked pleochroism can be observed: ω—light-yellow with a greenish tinge, ε—richer yellow-green. In crossed nicols all the known properties of rutile become apparent: parallel extinction with respect to cleavage fissures, marked reflection pleochroism covered up by the rich colour of the mineral etc. All these observations indicate very definitely that we are not dealing here with ilmenite as was postulated by the finder of the specimen but rather with *rutile.*

In order to verify the observations spectral qualitative analysis was carried out in the laboratory of the State Institute for Precious Metals in Prague (I. Raušarová) under the following laboratory conditions: Spectrograph ISP 22 with quartz optical parts, slit diameter 0.01 mm, electrode gap 3 mm, alternating arc, photographic plate Super-ortho Antihalo, exposure 20 sec., wavelength range 2230—4400 Å. It permitted to obtain the following estimate of elementary composition:

I. Essential (over 1%):	Ti,
II. Subordinate (1.0—0.1%):	—
III. Insignificant (0.1—0.01%):	Fe, Mg, Ca,
IV. Traces (below 0.01%):	V.

Titanium as a fundamental component belongs to the actual composition of the mineral, Fe and V are elements of isomorphic admixtures, Ca and Mg are elements of heterogeneous admixtures. These results indicate quite unequivocally that we are dealing with rutile with isomorphic admixture of a small amount of Fe and V. Rutile could be considered to contain a certain mechanical admixture of ilmenorutile or ilmenite and then the identified Fe and Mg could belong to this admixture. The occurrence of Ca detected spectrographically in rutiles is relatively frequent and could suggest a small amount of carbonate. For the sake of comparison of the results of spectral analysis an analysis of typical rutile from the well-known locality in Bamle in southern Norway was carried out. It yielded practically the same results with the exception of vanadium, but the quantitative proportion of elements was different. Thus it appears quite conclusively even from this line of approach that mineral in question is rutile.

Roentgenometric investigation was carried out by the powder method of Debye and Scherrer using the Mikrometa-Chirana apparatus under the following laboratory conditions: chamber diameter 57 mm, radiation $CoK_{\alpha\,1,2}$, $\lambda = 1.785$ kX, filter Fe, voltage 30 kV, intensity 15 mA, exposure 180 min., film Agfa Laue. The *d* values obtained are shown in Table 2. On comparing them with the values for rutile shown in the tables of *d* values a fine agreement of lines is apparent. It can be observed at the same time that the agreement in lines is better here than in the rutile from the Lazurový vrch since the mineral investigated contains less admixtures and inclusions. If the *d* values obtained are compared with those found in the tables for ilmenorutile, however, it may be seen that the rutile investigated is somewhat related to ilmenorutile as well. On the basis of microscopic investigation, of spectral qualitative analysis and roentgenometric measurements the mineral in question can be identified as a relatively very pure r u t i l e. As concerns the genetic situation of the rutile occurrence in the locality of Mastná bába it is possible to agree with the conclusions drawn by J. N o v á k (27) in his study on the rutile finds from this region. Among others, he mentions finds of rutile along with ilmenite and titanite in powerful, irregularly proceeding quartz veins in orthoamphibolites of the Mastná bába quarry. From the genetic point of view he reaches the conclusion that the localities of rutile in this area (l. c., p. 414) are directly associated with the pneumatolytic phase of Přibyslavice granite. The granite magma assimilated orthoamphibolites in the depth, the orthoamphibolites having a relatively high content of titanium. This phenomenon was then reflected in the formation of relatively abundant crystals of rutile and other titanium minerals in quartz veins penetrating through the surrounding rocks.

Both the above-described new finds of rutile coincide in many of their properties. Both finds were made in amphibolites but not directly in these rocks but rather in formations accompanying them (crystalline limestone, quartz and albite veins). They form relatively large individuals without crystalonomic bounding, always with apparent elongation in one direction, markedly rounded by surface resorption and not infrequently with signs of pressure effect. The rutiles are black to black-brown, in fine fragments they display brown to yellow-brown translucence, they are characterized by occasional semimetallic to metallic lustre and have a yellow to yellow-brown streak. Prismatic cleavage along (110) is only rarely well marked, mostly an uneven fracture being only observable. Roentgenometric data reveal a fine agreement with data for rutile from well-known localities shown in the tables and they definitely resemble more rutile than ilmenorutile; they are completely at variance with the *d* values for ilmenite.

B. New finds of ilmenite

Ilmenite from Cyrilov near Velké Meziříčí (Moravia)

In the crystalline body N of Cyrilov, SW of Horní Bory, NNE of Velké Meziříčí, occasional quite frequent small nests of quartz, minute crystals of garnet and pitch-black i l m e n i t e (inv. no. 33 675, O. Ronge, Hronov, 1941, legit) occur. The only reference to this occurrence can be found in the paper by E. B u r k a r t (3, p. 171) where the mineral is designated as rutile or possibly ilmenite, its tabellar development being emphasized. The find was apparently investigated in little detail and its conclusive identification was not carried out. It was therefore subjected to scientific revision.

A pebble of oval shape and about 40 X 25 X 20 mm in size was obtained from this locality, markedly rounded, with uneven surface. The Department of Mineralogy and Petrography of the Moravian Museum in Brno replied to our inquiry that a total of 5 pebbles can be found in their collections (Inv. A, no. 2990, from 1952, coll. J. Šťastný, Brno, no. 793) some of them possessing a reddish hue on their surface. Four of these pebbles are small, the fifth is split in half and measures 35 X 25 mm and weighs 30 g. The Department of Mineralogy and Petrography spared one of the pebbles for investigation; it measured 11 X 7.5 X 5 mm and weighed 1.361 g. Both the specimens investigated are oval in shape and have an uneven surface which displays at places a special structure which indicates either a druse-like termination of ilmenite crystals or could be due to imprints of some components of the mother rock. At places the surface is uneven, only little rounded, which indicates a limited transport of the pebbles. The colour is pitch-black, streak is black to black-grey, sometimes also with a light tinge to red-brown, lustre is marked semimetallic to metallic. Hardness, as estimated on the Soviet microsclerometer PMT-3 in a number of measurements yielded in most cases the value of 714 kg/mm^2, which corresponds roughly to the 5th grade of the Mohs scale. Investigation of magnetic properties revealed that the mineral does not affect the magnetic needle. On the other hand, on powdering finely the specimen some of the grains were attracted by the magnet. Hence it follows that the magnetism of the mineral is only negligible.

Thin sections prepared from both specimens indicate that we are dealing here with a fine-grained aggregate of lobe-like intergrown individuals, their size varying between 5.0 X 2.5 mm and 0.5 X 0.35 mm or even less. Especially the smaller individuals possess at places the thickly tabellar habit and basal type which suggest the common shape of ilmenite crystals with prevalent faces (0001) and $(10\bar{1}\bar{1})$. Cleavage is not apparent in the thin section. Only cracks proceeding at wide intervals in two directions can be observed, indicating most likely basal and rhombohedral divisibility rather than very imperfect cleavage of ilmenite along $(101\bar{1})$ which is suggested by some workers, e. g. A. G. Betekhtin (1, p. 370). This divisibility is caused mostly by twinny lamellae and is well marked especially during beginning decomposition. In transmitted light it has an apparent tinge to dark blue. At the finest edges only rarely a yellow-brown transclucence can be observed. In isolated cases the thin sections revealed locally relatively deep resorption, channels filled with fine flakes of biotite.

Chalcographic investigation made it possible to identify in the ilmenite elongate islands and bands of rutile which are concentrated particularly in the core of the pebble and only rarely penetrate to its edges. Rutile has a high reflective power and is light grey-white with a slight local tinge to yellow and therefore differs markedly from ilmenite which has a medium reflective power and a brownish colour. In rutile islands, quite frequent inner reflections of brown to red-brown colour can be observed. Ilmenite clearly predominates in the thin section plane and its content can be estimated at 85% of the total mass at the minimum. In the dark field of the microscope it is black to black-grey without inner reflections, in the bright field it has a light brown to yellow-brown tinge and exhibits marked anisotropy. Thus it can be concluded that we are not dealing here with a common admixture of isomorphic components (solid solution) but rather with a homogeneous aggregate of minute microscopic grains with remnants of rutile occurring generally only in subordinate role.

Spectral qualitative analysis was carried out under the same conditions as above in the laboratory of the State Institute for Precious Metals (I. Raušarová) and it yielded the following results:

I. Essential (over 1%):	Fe, Ti (Fe predominant),
II. Subordinate (1.0—0.1%):	Mg, Mn,
III. Insignificant (0.1—0.01%):	Sn, Ca,
IV. Traces (less than 0.01%):	V, Nb.

The results obtained can be interpreted as follows:

Elements forming the basis of the mineral:	Fe, Ti
Elements of isomorphic admixtures:	Mg, Mn
Elements of heterogeneous admixtures:	Ca, Sn, V, Nb

As concerns elements of heterogeneous admixtures we could be dealing here with minute to trace amounts of niobate and stannate (possibly kassiterite) the mechanical admixture of which in ilmenites has been repeatedly demonstrated.

Roentgenometric investigation of the specimen was again carried out according to Debye-Scherrer on the Mikrometa-Chirana apparatus under the following conditions: chamber diameter 57 mm, radiation $CoK_{\alpha\ 1,2}$, $\lambda = 1.785$ kX, filter Fe, voltage 30 kV, intensity 15 mA, exposure 120 min., film Agfa Laue. The results are shown in the attached Table 3. and show an agreement of the values found with the tabellar ones for ilmenite from wellknown localities. If the d values obtained are compared with those for rutile (as shown in Table 2.) marked differences between the two minerals can be observed.

To interpret the formation of ilmenite it was necessary to solve the problem of its mother rock which was identified as gneiss according to the paper of E. Burkart (3, p. 171). The Department of Mineralogy and Petrography of the Moravian Museum in Brno lent us their reference material from the same locality (no. 88, coll. J. Švancara, no. 2151) which was subjected to microscopic examination. The mother rock is grey-green, apparently considerably decomposed. It contains abundant minute (at most 0.4 mm) grains of red-brown garnet and at some places fine-grained aggregates of reddish quartz with minute black grains of ilmenite which are sparsely distributed throughout the rock itself (Table XXXVIII).

It was found microscopically that the fundamental components of the rock are a light-green common amphibole and a basic trabecular to columnar plagioclase resembling labradorite. Both these components are roughly in equilibrium and usually intergrow poikilitically. These are joined by subordinate large grains of pinkish garnet, only imperfectly bounded and at places by fine flakes and fragments of biotite and black-blue ilmenite only irregularly dispersed in larger, usually fringed grains. An interesting accessory is formed by apatite appearing in rounded grains. According to structure and composition the mother rock of ilmenite can be most probably identified as garnet amphibolite formed by mesozonal metamorphism of gabbrous rocks. Ilmenite is then a component of general metamorphism of the rock and was doubtless formed from the original components containing titanium.

Ilmenite from Moravany near Čáslav

An interesting find of ilmenite in the mother rock, orginally considered as rutile, was made in gabbrous rock NE of Moravany, SE of Čáslav (inv. no. 33 251, J. Kratochvíl, Praha, legit). Its actual locality is a hill (elev. pt. 335 m) NE of Moravany which is formed by gabbrous rock strikingly resembling amphibolite. According to the description published by J. Kratochvíl (19, p. 1) we are dealing here with a termination of a band of amphibolitic rocks pointing from Ronov-on-Doubrava to Mladotice and thence southward. J. Kratochvíl in his detailed petrographic study distinguished in the band three facies of gabbro: blue-grey (leucocratic), spotty green-grey and black-green which resembles dioritic amphibolites. He called attention to the existence (l. c., p. 18) of large kernels of a roughly crystalline rock formed by as much as 6 cm large individuals of pinkish zoisite and bytownite with veinlets of fibrous SiO_2, with inserted spinel and with grains of garnet at the edges. The island of gabbro near Moravany forms the southernmost known section of the band of gabbrous rock. It appears here quite isolated in the orthogneiss massif of Běstviny in neighbourhood of biotitic paragneisses in the southern Čáslav region.

The specimens with ilmenite belong undoubtedly to the third facies of rocks mentioned above as it is dark-green and macroscopically very much like diorite. It contains the above-mentioned kernels formed mostly by grey-white coarse-grained bytownite with dull to vitreous lustre on the cleavage planes. Ilmenite forms therein thin tabellar crystals about the size of 25×2 mm which grow either isolated or in clusters on gabbro walls (Table XXXVI b). The spaces between them are filled with bytownite. The crystals occasionally pass over even to fine-grained aggregates. Cleavage was never observed, fracture is always uneven, lustre semimetallic, occasionally metallic, colour black with a slight brown hue, streak black to black-grey.

Magnetism of the specimen is very slight as from a very fine powder of the material only few grains are attracted by a strong magnet.

In a powder preparation the opaque character of the mineral becomes apparent, together with a dark ink-blue colour, at places with an apparent tinge toward the violet. In fine flakes ilmenite exhibits red-brown translucence, in very fine flakes it may be even yellow-brown. The tabellar development of crystals and the very weak magnetism differentiate reliably this ilmenite from a similar magnetite or titanomagnetite which also appear dark-blue in incident light.

Roentgenometric investigation was carried out again according to Debye-Scherrer, using the Mikrometa-Chirana apparatus under the following conditions: chamber diameter 57 mm, radiation $CoK_{\alpha 1,2}$, λ = 1.785 kX, filter Fe, voltage 30 kV, intensity 15 mA, exposure 180 min., film Agfa Laue. The values obtained are shown in Table 3 and on comparing them with tabular values for ilmenite a good agreement between the two sets is apparent. If the values are compared with those for rutile (as shown in Table 2) striking differences in the *d* values may be observed. Optical examination was thus confirmed by the results of roentgenometric investigation.

From the genetic point of view appears without doubt that ilmenite represents a product of the last phase of development of gabbro and was formed simultaneously with bytownite. As concerns their mutual relation it appears that they crystallized simultaneously from the solution.—Ilmenite had been found in the region of the local gabbrous rocks even earlier. J. Kratochvíl (18, p. 243) mentions its occurrence in a pegmatite from the wide neighbourhood of Mladotice (most likely from Lhůty, E of Ronov-on-Doubrava) in tabellar irregular individuals as much as 3 cm in size. It occurs there together with nests of tourmaline grains intergrown with quartz and of lamellar basic oligoclase which is also intergrown which greenish quartz. In his great work on topography, J. Kratochvíl (20, p. 443) also mentions a find of ilmenite, or according to him of ilmenorutile, from Šauer's quarry on the left bank of the Doubrava where ilmenite occurs in pegmatitic veins in corsite. It forms there black columns, several cm in size, which have a cherry-red hue in their cores. On the basis of the three occurrences ilmenite can be considered to have been formed during the pneumatolytic phase.

Ilmenite from Putim near Písek

In deposits of the rivers Blanice and Otava near Putim, SSW of Písek, small pebbles have been found since time immemorial, the stones being generally designated as rutile or nigrine. During archeological excavations Na Pikárně not far from Putim, a number of such pebbles have been found in 1942 and they were sent to the Department of Mineralogy of the National Museum (inv. no. 34 010-34 011, B. Dubský, Čejetice, June 18, 1942 legit.). The occurrence of true ilmenite in deposits of the Otava near Písek was mentioned for the first time by A. Krejčí (23, p. 52; 22, p. 7) who refers to abundant black rounded grains as well as sharp-edged crystal fragments in each description published by him. Idiomorphic crystals of ilmenite were not found by him, however. He assumes that the specimens were brought by the Otava from the Šumava (formerly Böhmerwald) region.

Macroscopically, the pebbles are usually only 2×2 cm in size, some of them reach, however, a three-fold size, at the maximum 6×5 cm (inv. no. 34 010). Their surface is markedly rounded, at places also considerably uneven. A great majority of the specimens are unidirectionally elongated and frequently have a rectangular cross-section. Hence the original shape of these ilmenite crystals can be estimated; it was most likely thickly tabellar along (0001) with rhombohedral faces in lateral bounding. The colour is dark-grey, mostly completely black, occasionally with a fine brown tinge, streak is black-grey to black, lustre is predominantly semimetallic to metallic. Marked cleavage has not been demonstrated anywhere, only locally divisibility along (0001) is apparent. In some pebbles (inv. no. 34 010) rare intergrown grains of quartz or fine flakes of dark brown rutile can be found as they are betrayed by their colour and especially by their characteristic prismatic cleavage. In a powder preparation it can be seen that ilmenite is black-grey, at places black-brown in transmitted light (inv. no. 34 010) while in incident light it has a characteristic bluish hue and marked semimetallic lustre. Magnetism is again very weak, only some grains of the powder are attracted by the magnet.

Some very interesting properties of the mineral investigated were revealed by microscopic examination, both in thin sections and in polished sections prepared from the individual pebbles.

It was revealed by the thin sections that the macroscopically uniform material is actually formed by two main components. In spite of the fact that ilmenite remains here as the predominant mineral forming a greater part of the pebble edge its core is formed by rutile, into which ilmenite penetrates by long slender extensions mostly finger-shaped.

Ilmenite forms here an opaque mass which regularly predominates over the mass of the rutile core. The ilmenite shell may be as much as 4.25 mm thick (inv. no. 34 011) and it encloses occasional minute parts of rutile. Ilmenite then sends out irregular, mostly slender finger-like projections into rutile, the projections being roughly parallel with the vertical axis of rutile. It is black and in reflected light has a characteristic dark-blue tinge, occasionally also a well apparent light lustre. It should be mentioned at this point that its boundary with rutile is always markedly sharp, without the least trace of gradual transition so that in the given case it could be doubted whether A. Lasaulx (12) is correct in his assumption on the transformation of rutile into ilmenite which he observed especially on some rutiles from the vicinity of Vannes in southern Brittany in France.

Rutile is resctricted only to the core of the pebble and only in isolated cases does it penetrate with fine lamellae to the surface. It is bright yellow-brown in transmitted light, while in reflected light it is mostly light metal-grey, at places with yellow-brown bands. Even in reflected light of the polarization microscope it is always markedly lighter than the surrounding opaque ilmenite. At places, it exhibits rather marked pleochroism which is apparent especially in the change of saturation of the colour hue. ε—rich yellow with brown hue, ω—light yellow; absorption $\varepsilon > \omega$. In some parts of the rutile individuals the pleochroism is completely covered up by the rich darker colour of the mineral. Perfect prismatic cleavage is usually not clearly apparent. Rather abundant rough and irregularly proceeding transverse fissures, sometimes stressed by a filling of fine-grained ore pigment are very striking.

Each rutile core contains regularly inclusions of thin needles of sagenite, fine and coarser twinny lamellae and similar fine accretion zones.

Long thin needles of s a g e n i t e, 0.008 to 0.010 mm thick, occur here quite infrequently. They are mutually parallel and subtend an angle of 75^0 with the *c* axis. They were mentioned for the first time by G. H. O. V o l g e r (38, p. 495) as found in some crystals of rutile from Val di Vizze in southern Tirol and from the neighbourhood of St. Gotthard in Switzerland, later on by H. R o s e n b u s c h (33, p. 186) both from Val di Vizze and especially from St. Yrieux in southern Brittany in France, and finally by A. L a s a u l x (l. c., p. 56) from the neighbourhood of Vannes in southern Brittany. The last-named worker pointed out very fittingly that sagenite needles are light if rutile itself is in the extinction position as is the case in the specimen investigated.

Twinny lamellae are apparent in each rutile individual and they are regularly of two types: very fine and rather coarse. We are dealing here in all cases with an intergrowth along the deutero-dipyramid (101) which is most abundant in rutiles. The vertical axes of both individuals subtend then an angle of about 115^0. — Rutile contains most frequently very fine, mutually parallel, thin lamellae, about 0.020 to 0.048 mm thick. They occur in two systems which are deviated mutually by 45^0. They are sometimes characterized by denser pigmentation so that their course is apparent even in ordinary light. It is peculiar about them that they display no extinction. This interesting phenomenon was apparently correctly explained by A. L a s a u l x (l. c., p. 63) as being due to the position of differently orientated lamellae above each other.

Rather thick twinny lamellae reaching a thickness of 0.4 mm and containing further fine twinny lamellae represent a much rarer occurrence in rutile cores.

Another phenomenon which may be infrequently encountered are probably the accretion zones which appear in the form of parallel bands 0.016—0.064 mm in thickness, orientated perpendicularly to the *c* axis of rutile. They were formed most likely by aggregation of submicroscopic grains of rutile and they are not infrequently characterized by weaker pigmentation. From the twinny lamellae, they differ by orientation but they resemble them in lacking any extinction ability.

The colour of rutile, as was shown above, is not uniform and is due to the presence of very fine floccular dark-brown pigment. Rutile is usually yellow-brown in differently rich colour hues. It may be seen under high magnification that this original colour is due to very abundant, extraordinarily minute flakes reaching the maximum size of 0.004 mm, of steel-grey to grey-brown colour and possessing a frequently well apparent metal lustre. By both these properties they differ strikingly from the black opaque ilmenite. On the cracks this pigment is hydrated to become a light yellow limonite. It may be observed very frequently that especially along the irregular rough cracks the fine-flaked pigment was transported away through the cracks and rutile is thus coloured only light-yellow. Thus a certain decoloration of rutile took place here. According to the above-mentioned properties it may be concluded that hematite represents the rutile pigment. According to the data of spectral analysis, evincing constant presence of manganese it may be assumed that occasionally hematite was joined by some oxide of manganese.

On examining the distribution of hematite it will be observed that at places its fine flakes will accumulate at the extensions of ilmenite to the core of rutile where they form fine films. In the opaque mass of ilmenite these aggregate appear as roughly parallel filamentous structures which can be spatially represented as minute intercalations of hematite in ilmenite. They are very well marked due to its colour and structure. In the direction to the circumference of the pebble their number decreases. The boundary between ilmenite and hematite is always clearly defined so that an independent formation of each of the two minerals may be assumed. On the other hand, the boundary between hematite and rutile is not always so clear and occasional gradual transitions from the hematitic fine-flaked pigment in rutile to the fine-grained ranging to fine-flaked aggregates at the thin extensions of ilmenite may be encountered. As concerns the origin of hematite it can be assumed that it was originally at a higher temperature dissolved in rutile and formed a solid solution with it as mentioned by C. Doelter (5, p. 20). A. B. Edwards (6, p. 75) is of the opinion that rutile is eutectically related to hematite as he could demonstrate by his investigation of some rutile specimens from Western Australia and from Olara in South Australia. As far as the solid solutions are concerned it is assumed by A. G. Betekhtin, A. D. Genkin, A. A. Filimonova and T. N. Shadlun (2, p. 264) that during the decrease of temperature a partial or complete decomposition of the solutions takes place to give rise to simpler chemical compounds, the process resulting in the formation of very fine concretions, observable only microscopically. The degradation itself is a result of lowering the solubility of one of the components in the other and depends on cooling. However, there also exists experimental evidence of brown colour of rutile due to hematite which was presented by H. Traube (36). On fusing pure artificial TiO_2 with Fe_2O_3 he obtained brown rutiles, with 1.98% Fe_2O_3 opaque dark-brown rutiles were formed and with 5.4% Fe_2O_3 the rutiles formed were brown-red to almost black with marked pleochroism. On the basis of these results it can be rightly assumed that in the case investigated here a decrease in temperature took place resulting in a disturbance of the equilibrium and in deposition of hematite in the form of minute flakes, some of them were enclosed in ilmenite, some of them being concentrated on its extensions, others remaining dispersed in rutile and still another minor part being later concentrated in coarse cracks, hydrated and transformed into limonite or possibly transferred through the cracks into the surrounding rock.

At some places of the thin sections the rutile is rarely observed to contain minute remnants with pigment not yet deposited. They are light greenish and exhibit marked birefringence (very bright colours of higher orders). Their boundary with respect to the surrounding rutile is nonetheless very sharp. It could be therefore assumed that we are dealing here with a mineral related to rutile which forms only an inclusion therein.

Microscopic investigation of thin sections was then verified by examination on a chalcographic microscope, using several polished section prepared from the same material. In all cases, both the two main components of the pebbles are well apparent: ilmenite, as the predominant component, and rutile restricted in its occurrence to the core. Ilmenite predominates everywhere while rutile appears to constitute about one-tenth, at the most one-fourth of the total mineral material.

Ilmenite is characterized by its lower reflective power (but still higher than in sphalerite), by its grey colour with a greyish hue, marked anisotropy and total absence of inner reflections. Rutile is bright white, occasionally lightly cream-coloured, has a medium reflective power by which it can be clearly differentiated from ilmenite, as well as by the abundance of rich red-brown to brown-yellow inner reflexions in which then the black projections of ilmenite are particularly striking. The anisotropy of rutile is less marked.

Ilmenite forms a marginal shell about 10 mm thick and penetrates into the core of rutile by long thin extensions which are in the average 0.05 mm thick in the core. They often disperse but mostly are situated generally parallelly with the vertical axis of rutile. An alternation of fine parts of ilmenite with those of rutile represents a frequent phenomenon in some parts of the polished section.

The examination of hardness of the two components was carried out on the microsclerometer PMT-3, using the objective 32.6 x, F = 6.16, A = 0.65, with the eyepiece 15X and 50 g weight. The following values were obtained: ilmenite — 714 kg/mm^2 (about 5 according to the Mohs scale); rutile — 908 kg/mm^2 (about 5.5 according to the Mohs scale). The density of ilmenite with rutile was determined pycnometrically and found to be 4.3 which corresponds to the average density of the two components. An accurate determination of density of each component could not be carried out on account of the impossibility to obtain pure material for the investigation.

Qualitative spectral analysis carried out with the inseparable mixture of both above-mentioned components was carried out in the laboratory of the State Institute for Precious Metals in Prague (J. Raušarová) under the same conditions as above and yielded the following results:

I. Essential (over 1%):	Fe, Ti (Fe clearly predominant),
II. Subordinate (1.0—0.1%):	Mn, Mg,
III. Insignificant (0.1—0.01%):	Sn, Ca.
IV. Traces (less than 0.01%):	—

According to the data obtained the elements can be classified as follows:

Elements forming the basis of the mineral:	Fe, Ti.
Elements of isomorphic admixtures:	Mg, Mn, Sn.
Elements of heterogeneous admixtures:	Ca.

The predominance of Fe over Ti in the fundamental elements is caused not only by the predominance of ilmenite over rutile but also by the presence of fine-flaked hematite. Mg and Mn are usual isomorphic admixtures of ilmenite as follows from the assumed and partly verified isomorphic series between ilmenite, geikielite and pyrophanite. It is of interest to note the presence of a small amount of Sn where its isomorphic character (related ionic radii) could be presumed. On the other hand, an admixture of stannate to ilmenite could be also considered in the form of a mechanical admixture as had been repeatedly demonstrated. Small amounts of Sn in analyses of ilmenite are known from the analysis carried out by C. G. Mosander (26) and C. F. Rammelsberg (31) from localities in the vicinity of Arendal in southern Norway where the samples contain as much as 3.64—3.68% SnO_2. Ilmenites from Mias in Ural in the USSR also contain 0.50% SnO_2, according to the analysis carried out by A. Delesse (4). Ca belongs finally to the rather frequent minute mechanical admixtures either of carbonate or of silicate.

Roentgenometric investigation was carried out according to the powder method of Debye-Scherrer under the following conditions: Apparatus Mikrometa-Chirana, chamber diameter 64 mm, radiation $FeK_{\alpha\ 1,2}$ $\lambda = 1.933$ kX, filter Co, voltage 30 kV, intensity 15 mA, exposure 180 min., film Agfa Laue. The values obtained are shown in Table 3 and compared with the values for ilmenite found in the standard tables. A good agreement of the two sets of values is evident, on account of the fact that a section from the marginal part of the specimen formed mostly by ilmenite was used.

The primary locality of the Putim pebbles formed by ilmenite and rutile should be sought in the extensive area of the moldanubian crystalline body of Šumava. Their mother rocks can be either quartz or pegmatite veins in the crystalline body or isolated islands and bands of amphibolites and related basic rocks in the river basin of Otava or Blanice (S of Prachatice or W of Sušice and elsewhere). The relatively large occurence of pebbles of ilmenite with rutile in the neighbourhood of Putim is in agreement with the results of investigation of heavy minerals in the deposits in SW Bohemia which was recently undertaken by A. Kodymová (15). The author reached the conclusion that the amount of heavy minerals in river deposits increases in the direction from the source to the mouth which is in agreement with the occurrence of ilmenite with rutile in the sediments of Otava and Blanice, particularly abundant in their lower courses and near the mouth.

Ilmenite with rutile from Bražná near Kamýk-on-Vltava

In the valley of the creek Selná, W of Bražná, NNE of Krásná Hora, ESE of Kamýk-on-Vltava, remnants of old gold-washing places have been known for a long time. A. Irmler (11) called the attention to the extraordinary area of the local deposits and to frequent gold-washers' hills, some of them reaching a height of 6 m. In the sediments, powder gold with large proportions of silver was fairly abundant. Still in 1941, the former Ministry of Public Affairs worked in the deposits and the concentrates were found to contain relatively abundant pebbles and fragments of a mineral marked as iserine (inv. no. 33 619) accompanied by abundant quartz, garnet, fine-powdered magnetite and minute yellowish grains of zircone.

Macroscopically we are dealing here with abundant pebbles of 1 cm in size together with smaller fragments. They are usually unidirectionally elongated which indicates the original, most probably columnar development. Their surface is markedly rounded, dull, only at the fresh fracture faces a semimetallic, occasionally quite intense lustre is apparent. Colour is black to black-grey and streak (determined by several observations) is of the same colour. Cleavage is not apparent macroscopically, it appears that the mineral does not exhibit any cleavage and possesses only an uneven fracture. By their general appearance the pebbles from Bražná do not differ markedly from the pebbles found in the neighbourhood of Putim. A stronger magnifying glass permits to see that the macroscopically homogeneous mineral is not simple as at places some lighter red-brown parts may be observed quite clearly, differring very strikingly from the colour of the surrounding mass. In the powder preparation, only fragments of opaque ilmenite could be detected, as betrayed by their black colour with bluish hue, but at places also by a marked violet tinge. Magnetism is very low as only very few grains of the powder are attracted by a strong magnet.

Microscopic investigation was carried out on a number of thin sections prepared from small pebbles and orientated approximately perpendicularly to the vertical axis of the original rutile crystal. All the thin sections, in common with the preceding case, revealed immediately a transparent, light yellow or mostly brown-yellow core of rutile, surrounded by an opaque envelope of black ilmenite which displayed in reflected light a clearly marked blue tinge, more rarely a slightly violet one, as well as apparent metallic lustre. In contrast to the material obtained from the vicinity of Putim it appears here that in Bražná rutile frequently predominates over ilmenite, the envelope of which is usually thinner and in the thin section forms an estimated one-fifth of the total area of the thin section.

I l m e n i t e forms here not only a continuous compact envelope of the rutile core of about 1.28-0.8 mm in thickness but it also penetrates into the core in the form of abundant thin projections which appear as fine thin lamellae on thin sections parallel to the vertical axis, the lamellae reaching the thickness of 0.13-0.16 mm. Sometimes they have the form of short lentils, about 0.15 mm in length. It may be observed in all sections of this type (Table XXXVII., Fig. 2—4) that these structures are always associated with fissures of prismatic cleavage. On sections roughly perpendicular to the vertical axis (Table XXXVII., Fig. 1) it may be clearly established that most of these fillings follow clearly the course of fissures of marked cleavage (100) only. Cleavage fissures along (110) which are usually denser and longer since we are dealing here with perfect cleavage, usually do not contain any ilmenite. The fillings of cleavage fissures form sometimes mutual anastomoses and in the direction toward the edge of the pebble their number markedly increases so that they pass over to the compact ilmenite envelope. On the other hand, their number decreases in the direction toward the core centre when mostly quite short, sometimes irregular lentils of average size of 0.3 × 0.1 mm occur in their place. It follows from the above-said that the riches of ilmenite fillings is directly proportional to the distance from the centre of the rutile core where a marked reduction of their number takes place. In common with the finds from Putim, the Bražná specimens display a sharply defined boundary between ilmenite and rutile which excludes the view expressed by A. Lasaulx (24) concerning the formation of ilmenite by transformation of rutile, at least as far as the finds described here are concerned. It follows from the description that ilmenite, by its appearance and type of occurrence, frequently resembles quite indistinguishably the ilmenites from the vicinity of Putim.

Rutile forms the core of the pebbles and reaches the maximum size of 5.0 × 4.5 mm in the thin sections examined. The bounding of the rutile core is always imperfect, crystal faces were never present even in traces. The elongation in the direction of fissures of prismatic cleavage suggests in most cases the common shortly columnar habit of its crystals. Surface resorption is apparent everywhere, resulting in a marked rounding of the crystal as well as in the occurrence of occasionally relatively deep resorption channels.

The colour is not always the same and displays considerable variability. In some thin sections the core is coloured rich lemon-yellow, in other cases the colour is light brown with a marked yellow tinge. In both these cases pleochroism was absent. In other sections two colours could be observed. The yellow-brown to orange-brown colour predominates but along the cleavage and fracture fissures the mineral is coloured light lemon-yellow. The boundary between the two colours is not sharp but is always well apparent. A rather intense pleochroism represents an accompanying phenomenon of the mentioned colour but it manifests itself only in a change in the saturation of the colour hue with the usual absorption $\varepsilon > \omega$. Pleochroism is particularly marked in the predominant parts of rutile coloured yellow-brown. In rutile cores coloured by these two hues a certain decoloration of rutile along the cracks can be considered as was also observed in the specimens from Putim.

The fissures of perfect cleavage along (110) are occasionally completely invisible, at other times, on the contrary, they are very dense, rectilinear, extraordinarily abundant but relatively short. In sections roughly perpendicular to the vertical axis it is possible in such cases to observe the angle of cleavage fissures conjugate to the value of 90^0. The fissures of apparent cleavage along (100) could not be detected in the thin sections and they are only traced by the course of ilmenite lamellae. Practically every thin section contained coarse irregularly proceeding fissures cutting across the rutile crystal which were formed by high pressure acting on relatively fragile and breakable rutile individuals.

These thin sections also revealed fine long needles of sagenite which are somewhat thicker than those from neighbourhood of Putim reaching a thickness of mostly 0.016 mm, but maximally also 0.032 mm. They are best apparent in the extinguishing position of the rutile core. They form two systems of needles subtending an angle of about 50° which corresponds to the deviation of sagenite needles in aggregates known from various localities. They subtend an angle of 57—67° with the vertical axis of the rutile core. Their extinction is not always clearly apparent. Twinny lamellae occur in practically every one of the thin sections and have exactly the same character as in the finds from Putim. Some coarser twinny lamellae along (101) are striking as they are met quite frequently (Table VI, Fig. 2). There also a penetration of ilmenite orientated along the cleavage fissures (100) can be observed. Twinny lamellae of this type are frequently very fine, reaching an average thickness of 0.016 mm and are betrayed by their oblique extinction. Under strong magnification, however, transverse fissures of prismatic cleavage can be observed in them, the fissures containing occasionally lamellae of ilmenite where by their true twinny character can be verified. Only in isolated cases, twinny lamellae along (301) at an angle of 55° with the vertical axis could be found. Accretion zones perpendicular to the vertical axis and reaching a thickness of as much as 0.032 mm were occasionally observed which suggest a zonal growth of some parts of the rutile core. They are visible only between crossed nicols, otherwise they are only rarely emphasized by more marked pigmentation.

In common with the finds from Putim, here also a fine-flaked hematite can be observed, apparently separated from rutile which either accumulated in the form of a frequently unilateral border of thin ilmenite lamellae projecting from the edge to the core or was transported away through the cleavage and coarse fissures so that a decoloration of rutile took place. The mineral lost its original red-brown hue and took up a lemon-yellow one, together with a considerable decrease or even complete loss of pleochroism. The hematite pigment can be detected under crossed nicols on account of its characteristic steel-grey to blue-grey colour and marked metallic lustre, apparent especially in reflected light. Thus we again reach the conclusion that the fine-flaked hematite pigment after separation from rutile migrated to the extensions of the materially related ilmenite or accumulated in fissures and was transported away through them.

Chalcographic investigation was carried out on a total of seven polished sections of different orientation. In common with the previous case, it was possible here, too, to demonstrate quite reliably its two principal components: ilmenite, markedly brownish with lower reflective power and little marked anisotropy, and rutile, bright white or slightly yellowish with medium reflective power, marked, occasionally very strong anisotropy and always with abundant strong red-brown inner reflections, by which it particularly markedly differs from ilmenite. It was often estimated in the polished sections that the two components are roughly in equilibrium but that mostly the ilmenite component predominates, which is to a certain degree at variance with the findings of polarization microscopy. In some polished sections, orientated roughly perpendicularly to the vertical axis of rutile, ilmenite lamellae following the course of cleavage fissures along (100) and occasionally crossing at an angle conjugate to 90^0 could be detected, which is in agreement with the findings made in the polished section. In sections parallel to the vertical axis it was frequently possible to observe finger-like penetration of ilmenite into rutile fissures.

In order to verify further the identification of the two components a microsclerometric determination of hardness was also carried out, which took place under the same conditions as shown above. The following values were obtained: for ilmenite 810 kg/mm^2 which corresponds roughly to the 5th grade of the Mohs scale, and for rutile 1027 kg/mm^2 which corresponds to a higher value, namely about 5.5 on the Mohs scale. The density of the mixture of the two minerals (since they cannot be separated reliably) was determined pycnometrically as 4.81, which indicates that the specimen was probably completely pure ilmenite. For spectral and roentgenometric investigation a mixture of the two minerals had also to be used, ilmenite being the predominant component. Spectral analysis was carried out in the laboratory of the State Institute for Precious Metals (J. Raušarová) under identical conditions as above and yielded the following results:

I. Essential (over 1%):	Fe, Ti,
II. Subordinate (1.0—0.1%):	Mg, Mn, Ca,
III. Insignificant (0.1—0.01%):	Sn.
IV. Traces (less than 0.01%):	—

In discussing the results obtained and on comparing them with the rough estimates obtained by spectral analysis of the material from Putim a marked agreement between the two can be observed, both as concerns the isomorphic admixtures (Mg, Mn, Sn) and the heterogeneous admixture of Ca. We are thus dealing with minerals which are identical in their qualitative composition and most likely differ only insignificantly in the quantitative composition.

Roentgenometric investigation also suggests some relationship between both minerals. It was carried out according to Debey-Scherrer's powder method under the following laboratory conditions: Apparatus Mikrometa-Chirana, chamber diameter 57 mm, radiation $CoK_{\alpha 1, 2}$, $\lambda = 1.785$ kX, filter Fe, voltage 30 kV, intensity 15 mA, exposure 120 min., film Agfa Laue. The values obtained are shown in Table 3 and compared with those for ilmenite found in the standard tables as well as with the results of roentgenometric investigation of ilmenites from the other new localities. The values are closest to those for ilmenite from Cyrilov and from Moravany. When the probably primary localities of rutile with ilmenite from Bražná are considered it must be taken into account that the creek Selná, in the deposits of which they occur passes in its entire course through an area formed by amphibolitic-biotitic granodiorite. At the upper course of Selná there occur abundant veins of lamprophyric rocks, aplites and pegmatites. In the lower course the lamprophyric veins recede completely. Under these geological conditions it appears likely that the primary locality of rutile with ilmenite should be sought most probably among the more basic facies of amphibolitic-biotitic granodiorite or among the local differentiates of basic character which belong to granodioritic magma. It is, however, possible that they originate even from some pegmatite veins in which rutile was also occasionally found, e. g. in Madagascar. In the weakly metamorphic rocks of the Sedlčany-Krásná Hora island the occurrence of rutile in minute individuals only can be assumed, not to mention the fact that the locality is 1—2 km away from the course of the Selná. The possibility of primary localities of rutile with ilmenite in the granodiorite region is thus even more emphasized.

Comparison of structure of new finds of rutile with ilmenite with older analogous occurrences

The interesting results of microscopic examination of pebbles of rutile with ilmenite, commonly described as nigrine and found especially in the deposits of tributaries of the Vltava, particularly on the lower course of the Otava served as stimulus for comparing them with finds of similar minerals described earlier from deposits in the region of Šumava crystalline body. The literature knows so far of two more important localities in the deposits of the upper course of the Otava, namely near Malonice and in the vicinity of Nekvasovy, some 25 km distant from each other.

M a l o n i c e, NNW of Velhartice, SSE of Klatovy, were considered as early as the twenties of the last century as the main locality of rutiles in Bohemia. The mention by J. S. P r e s l (28, p. 112—114; 29) dates back to that time; he described pebbles considered first as ilmenite, later on described by F. X. M. Z i p p e (40, p. 45) as nigrine. It occurs relatively abundantly in small about bean-sized black pebbles in the sands especially between Malonice and Jindřichovice and has its origin most likely in gneisses.

The thin section prepared from such a pebble (inv. no. 11497) reveals roughly the same picture as was observed in thin sections of specimens from Putim and Bražná. While the opaque ilmenite forms an envelope representing an estimated 90% area of the thin section, rutile is restricted to two round and differently orientated grains in the core which are also densely penetrated by parallel and perpendiculary crossing ilmenite lamellae.

Ilmenite is opaque, black with a marked bluish hue and does not differ from ilmenite from the preceding localities. Occasionally its divisibility becomes apparent as observed also macroscopically. Alternating with ilmenite, slender parallel fine-flaked filamentous parts formed by steel-grey to blue-grey hematite can be found, the hematite occurring also on the circumference of the ilmenite lamellae in rutile cores and passing slowly over to the thinly dispersed rutile pigment.

Rutile forms two rounded parts in the core. Their sizes are 1.76×0.73 mm and 1.60×1.04 mm, their colour is grey-yellow and in reflected light dark steel-grey, probably due to the hematite pigment. They display marked pleochroism: ε—light yellow-brown, ω—grey-yellow, absorption $\varepsilon > \omega$. According to the orientation in both sections, ilmenite lamellae apparently form continuous fillings of cleavage fissures along (100). Lentil-shaped forms known from the thin sections of the Bražná material are lacking here.

Generally it appears that we are in no case dealing here with a formation of larger rutile individuals and that, on the contrary, intense crystallization of ilmenite about rutile individuals took place. It follows from the description, however, that there is no basic difference from the new finds of ilmenite with rutile, there being an identity both as far as the composition is concerned and in their microscopic structure.

A. Hofmann and F. Slavík (9, p. 27), in describing the gold-bearing area of Kasejovice were the first to mention finds of rutile pebbles (nigrines) from the eastern vicinity of Nekvasovy, WSW of Kasejovice, E of Klatovy. The specimens in question are pebbles, abous 1.5 cm in size, black, occasionally preserving the form of the original individuals or twins. The authors maintain that even macroscopically a fresh fracture would reveal the transformation of rutile into ilmenite which is manifested by a marked difference between the red-brown core and the metal-black outer shell, several mm in thickness. Microscopically the course of transformation is reported to be well apparent to proceed from the outside along the cleavage cracks. The authors point out explicitly the conformity of this structure with the description presented by A. Lasaulx (24), especially as concerns rutile from St. Yrieux in Brittany. The rutile of Nekvasovy is characterized by marked pleochroism between a red-brown and orange-brown colour and contains abundant interposed twinny lamellae. — As follows from the presented description from this locality the finds do not appear to differ from the new finds of ilmenite and rutile.

The finds of titanium minerals from their classic locality on the Jizerská louka in W Krkonoše (Giant Mts.), NE of Jablonec-on-Nisa, close to the state border, were used here as reference material. The sandy deposit of the Jizerka has been known for long to contain, in addition to precious stones (especially saphires, rubies and spinels), rounded crystals and fragments of rutile, of its black variety nigrine, but most frequently pebbles and small grains of iserine, the black variety of ilmenite. Iserine occurs in the deposit very abundantly especially in small grains and pebbles reaching up to 3.5 cm in size, occasionally weakly magnetic. It is mentioned in the text-books from the beginning of the last century, particularly by F. A. Reuss (32, p. 598) and G. Leonhard (25, p. 479). M. H. Klaproth (14, p. 208) identified it as a variety of titanium iron (ilmenite), a view generally accepted until recent times. Newer text-books, however, express some doubts as to the correctness of this identification, pointing out that we may be dealing here rather with rutile with a fraction of trivalent iron. P. Ramdohr (30, p. 707) calls attention to the fact that it has been demonstrated that most iserines as well as nigrines must be considered as mixtures of rutile with ilmenite. Most recently, H. Strunz (35, p. 382) maintains that iserine is composed of ilmenite frequently pseudomorphosed by rutile. It follows from these very latest findings that the composition of the pebbles taken formerly for pure ilmenite comprises two components, in common with the new finds described here. J. V. J a n o w s k y (12) described in the eighties of the last century a new similar mineral in the deposits of the Jizerská louka, the mineral being named iserite. According to the results of his own qualitative chemical analysis he took it for a new iron titanate of the formula $FeTi_2O_5$. It occur in the deposit in the form of 1—2 cm large black-brown grains with imperfect cleavage and with forms resembling rutile crystals. In fine layers it displays amber-coloured translucence. It was not long, however, before P. G r o t h (7) expressed serious objections against the existence of an independent mineral and he concluded that we are more likely dealing with nigrine. This view found support of A. G. B e t e k h t i n (1, p. 392) who comments that we are most likely dealing here with a variety of rutile, richer in iron than nigrine. M. H. H e y (8, p. 46) and H. St r u n z (35, p. 383) also express doubt in their new lists of minerals as to the justification of the name which is being now considered as superfluous.

Both iserine and iserite, however, are interesting for comparison with the above-mentioned findings on ilmenite and rutile from southern Bohemia. The thin section of iserine (inv. no. 22003) reveals only a minute rutile core about the size of 0.4×0.06 mm which is surrounded by the predominant mass of opaque ilmenite which forms an envelope about 1.28 mm thick. In the finest layers it shows brown translucence, otherwise it is black with a dark-blue tinge. Rutile in the core is light yellowish, is not pleochroic and has markedly high interference colours which are well apparent as contrasted with the other finds where the high reflection pleochroism is covered up by the rich colour of the mineral. Rectilinear cleavage cracks are very rare, much more frequent are the minute, irregularly proceeding cracks. On considering the mutual relationship of the two minerals it may be seen that ilmenite appears to penetrate through minute, occasionally markedly composite folds into rutile so that the rutile core is gradually reduced to a network resembling the leaf nervature. Hence it may be deduced that the replacement of rutile by ilmenite was here very intense. In addition to the eccentrically situated rutile core the ilmenite shell is observed to contain occasional minute parts of rutile. — In spite of various small deviations in the properties of the two minerals a generally identical microscopic picture can be seen here as in the new finds of pebbles of rutile with ilmenite and it may thus be concluded that the origin of the two was analogous.

The occurrence of rutile with a very similar microscopic structure was described from alluvial deposits of the southern part of the Kiev region in the USSR by J. J. Y u r k a n d S. M. R y a b o k o n' (13) who distinguished reliably two varieties of rutile. As primary rutile they consider the cherry-red type without iron which was found in the form of small grains more frequently in the surrounding rocks, most often in the pegmatites, in isolated cases also in biotic gneisses and granites which intrude into the former. A second, completely different variety is represented by the black rutile with semi-metallic to pitch lustre. It is surrounded by an amorphous envelope which was found microchemically to contain Fe in addition Ti. The last-named variety of rutile has not been hitherto detected in the surrounding rocks. For this reason the authors are of the opinion that this variety of rutile was formed secondarily during degradation of primary rock components containing Ti (mainly titanite, ilmenite and isomorphic admixtures in pyroxenes, amphiboles, in biotite and in garnets) brought about by the action of surface water and of atmospheric H_2CO_3. — According to the description presented we are dealing here with pebbles of rutile with ilmenite which are very similar to the finds from southern Bohemia. The authors unfortunately do not present a more detailed description of their structure and do not exactly define the character of the envelope which undoubtedly belongs to ilmenite. In order to treat objectively the views of both workers it would be necessary to attempt to find the primary locality of rutile with ilmenite in the region of southern Bohemian crystalline body which would then solve unequivocally the problem of origin of these minerals.

Problem of primary localities of rutile with ilmenite

At the beginning of the present paper, in describing the individual new finds of rutile with ilmenite their probable primary localities were briefly discussed. It was essential to find whether in S or possibly SW Bohemia there may not exist the well-known primary localities of rutile with ilmenite in sufficient quantities so as to permit of considerations of the origin of pebbles found in river sediments. As far as I know, only a single case of this type was reported from the area, namely an isolated occurrence of pyroxene-garnet hornstone near Hutě, NE of Bechyně. The rock is denuded by the Kameník quarry (elev. pt. 420 m.) NE of Hutě. Rutile, together with other minerals was described there by K. Tuček (37, p. 89—95), the rock was more accurately described by F. Kratochvíl (17, p. 518—520).

The pyroxene-garnet hornstone from Hutě represents one of the frequent inlays in the extensive crystalline complex, formed mostly by biotitic of biotite-sillimanite orthogneisses of the moldanubian body. It is dark-grey to dark-green, it is very fine-grained and even macroscopically remarkable by its abundant grains of red-brown garnet. At places it also contains interesting amphibolic facies of coarser grain. By microscopic investigation of its specimens (inv. no. 34508) it is possible to estimate the percentage of pinkish garnet at 80%, the garnet occurring in markedly rounded, occasionally mosaic-arranged grains of maximum size 4.5 mm, in the average only 1.25×1.00 mm large. In the spaces of garnet grains a weakly pleochroic common amphibole crystallized (α—light brown-green, β and γ richer brown), mostly in small (up to 1.25×0.75 mm) individuals. Some garnet grains are enclosed by fine amphibole bands which can be taken as evidence for an approximately simultaneous crystallization of both minerals. Many of the garnet grains possess a kelyphytic envelope up to 0.75 mm in thickness, which is formed by fine light-green fibres of amphibole which appears to be the result of a reaction between the garnet and its surroundings.

A striking phenomenon in the thin section is represented by a large crystal of rutile, the clusters of which in the rock reach the size of 4 cm.

In the thin section it is characterized by its dark-brown colour, rounded and markedly corrugated edge and deep resorption channels. It displays a relatively intense pleochroism, apparent in the change of saturation of the hue. ε—dark-brown, ω—light yellow-brown, absorption $\varepsilon > \omega$. In common with some of the new finds of rutile with ilmenite, here also a non-uniform colour of analogous type can be observed. Along the coarse cracks the colour is much lighter, being either light-brown or yellow-brown, in reflected light dark-brown. The rectilinear sharp cracks of prismatic cleavage, as well as abundant coarse irregularly proceeding transverse cracks are very striking. In all these properties the rutile from Hutě coincides with that of the new finds. The agreement is also well pronounced in the presence of black to black-blue opaque ilmenite the ratio of which here is considerably lower than in new finds of rutile with ilmenite. Its ratio can be estimated at mere 5% of the total rutile mass (according to the thin section). It is concentrated mainly at the edge of rutile where it forms a continuous border but at places it is apparent even in the above-mentioned channels or in their immediate vicinity. Its bounding with respect to rutile is again quite sharp. On a section of rutile roughly perpendicular to the vertical axis it may be observed that ilmenite follows again the cleavage cracks of rutile along (100) which it partly fills. Of particular interest, however, is the filling of deep and slender resorption channels which are only partly filled with ilmenite, as they contain in the centre small and larger columns of greenish amphibole.

F. Kratochvíl (l.c., p. 520) concludes on the basis of the described mineral composition that the hornstone was formed by contact transformation from dolomitic limestone contaminated with a loamy substance during the period of regional pressure.

On the basis of microscopic examination the following probable origin of the rock can be envisaged:

1. First to crystallize were minute grains of ilmenite.

2. During the next phase a roughly simultaneous crystallization of amphibole and garnet takes place, the garnet possessing greater crystallization pressure and enclosing minute columns of amphibole. Probably during this phase the crystallization of large, skeleton-shaped crystals of rutile took place; at the same time, ilmenite begins to accumulate about the crystals.

3. Powerful resorption of rutile connected with penetration of ilmenite grains into the formed resorption channels and cleavage cracks along (100) follows.

4. During the terminal phase the crystallization of amphibole culminates, the latter filling all spaces between the grains of garnet and penetrating into the corrosion channels of rutile where it may occasionally replace ilmenite.

On the basis of these considerations it can also be envisaged under what conditions the formation of the newly described finds of rutile with ilmenite took place in their primary localities where there was undoubtedly considerably more ilmenite than in the hornstone from Hutě. We can then assume the existence of mother rocks either of a similar character as the hornstone described here or of basic differentiates of granodioritic magma. As far as the mother rocks of rutiles are concerned it was found that the rutiles are mostly associated either directly with the metamorphic processes of amphibolites (rutile from the Lazurový vrch) or with products of granite pneumatolysis penetrating through amphibolites (rutile from Podmoky). However, the same holds very probably for the occurrence of ilmenite in Moravany and of ilmenite with rutile in Cyřilov.

In the free pebbles of ilmenite with rutile core from Putim and from Bražná it can also be assumed that they are closely connected with amphibolic rocks. In the first case we could be dealing with pneumatolytic veins penetrating through islands of Šumava amphibolites, in the second case then at least with more basic differentiates of magma of amphibolite-biotite granodiorite as we mentioned above.

General discussion of spectral analyses

In order to verify and confirm the findings obtained by studying the material in polarization and chalcographic microscope, qualitative spectral analyses of most new finds of rutile and ilmenite were carried out in the Laboratory of the State Commission for Precious Metals (I. Raušarová). In addition to that, spectral analyses of suitably selected rutiles and ilmenites from their classical localities both here and abroad were carried out in order to obtain reliable reference values. Such specimens were especially selected as were macroscopically fairly identical with the specimens described and as could also supply relatively pure homogeneous material for investigation. The new specimens were treated so as to yield also the purest possible material from the surface part but still the presence of rutile in ilmenite could not be always prevented as we are dealing very frequently with very intimate intergrowths which cannot be separated by the most careful methods. Spectral analyses were carried out on the ISP 22 spectrograph with quartz optical parts, slit width 0.010 mm., electrode gap 3 mm., alternating arc, photographic plates Superortho antihalo, exposure time 20 sec., wave-length range 2230—4400 Å, source FF 20, 0.08 mH, 3000 pF and 1000 V. The data obtained are shown in Table 1.

If the results obtained for the individual minerals investigated are compared with each other and with the values for rutiles and ilmenites from other localities the following common conclusions can be reached.

1. Spectral analyses of rutiles differ at first sight very strikingly from the spectral analyses of ilmenites which contain fundamental amounts of Fe. In the rutiles, Fe represents only an insignificant element even if, on the other hand, the external features of the two minerals are often practically indistinguishable.

2. All the ilmenites investigated contain Mg in the form of isomorphic admixture and Ca as a heterogeneous admixture. Both elements are either subordinate or insignificant; the proportion of Mg decreases in both cases to trace amounts.

3. The new finds of ilmenite from Cyrilov, Putim and Bražná are estimated to contain basically the same amounts of elements as those

from the Ilmen Mts. and from Krageroe, or even from nigrine from Malonice of from iserine from the Jizerská louka.

4. Ilmenites from Cyrilov, Putim and Bražná have a very similar composition and coincide both qualitatively and roughly quantitatively.

5. The lack of Nb and Ta distinguishes the new finds of ilmenite with rutile core quite reliably from the ilmenorutile from Tefina on Madagascar which was used for comparison.

It follows from the above-said that carefully performed spectral analysis can represent one of the reliable methods for mutual distinction between frequently very similar and macroscopically indistinguishable occurrences of rutile and ilmenite.

On the basis of a comprehensive discussion of spectral analyses of all new occurrences of ilmenite it can be summarized that

(a) elements forming the basis of the mineral are Fe and Ti;

(b) elements of isomorphic admixtures are Mg and Mn;

(c) elements of heterogeneous admixtures are Ca, Sn, V and Nb.

As to the ratio of Fe:Ti it was found by spectral analysis that in ilmenites from Cyrilov and from Putim there is a marked predominance of Fe over Ti while in the ilmenite from Bražná the two elements are practically in equilibrium. It is possible that in the first two cases a part of Fe is associated with the separated hematite since the mother liquor contained more Fe than would be required for the formation of ilmenite.

Mg and Mn represent the common isomorphic admixtures of ilmenite and they prove its isomorphic relationship to geikielite as well as to pyrophanite with which the ilmenite appears to form continuous isomorphic series. Ca indicates most probably that there is a heterogeneous admixture of basic silicates of the mother rock which hold for all the three new finds of ilmenite. Calcite or another carbonate were never detected in them. Of interest are the admixtures of Sn, V and Nb which can be most simply explained as a mechanical admixture of rutile or ilmenorutile. Both these minerals can according to the view of W. T. Schaller (34) contain in addition to fundamental amounts of Ti, Fe and Nb also isomorphically admixed cassiterite and a small amount of titanyl vanadate.

Summary of the results of investigation of new finds of ilmenite with rutile

If we now attempt to summarize the results obtained by the investigation of new finds of ilmenite with rutile it may be found that we are mostly dealing with pebbles about 2—4 cm in size or with their fragments from sediments. The pebbles are usually unidirectionally elongated, markedly rounded and have an uneven surface. Their colour is black to black-grey, in fine fragments under the microscope they display a brown to yellow-brown translucence; their streak is black to black-grey and their lustre is semimetallic, on fresh fragments sometimes even metallic. In a powder preparation and in a thin section ilmenites are opaque, rutiles are brown-yellow or even light-yellow, depending on the admixture of fine flaked hematite. Ilmenite, particularly in reflected light, shows usually a bluish, sometimes a violet tinge. Cleavage is never apparent in ilmenite, only rarely basal or rhombohedral divisibility is indicated. The rutile core exhibits particularly well the cracks of perfect cleavage along (110) but more frequently we encounter here rather coarse, irregularly running transverse cracks due to pressure. The fracture of pebbles on the surface is always uneven.

The pebbles and fragments display but very weak magnetism. Hardness of ilmenite, as estimated microsclerometrically, corresponds to about 5 on the Mohs scale, that of rutile is higher, corresponding to about 5.5. Crystals of rutile and ilmenite with rutile core always display signs of heavy resorption which is particularly pronounced in the samples of these minerals in primary rocks. Then not only a surface rounding can be observed but quite frequently rather deep resorption channels (rutile from the Lazurový vrch, from Podmoky and from Hutě near Bechyně). All grains from the deposits are markedly rounded and mostly undirectionally elongated.

In three out of six finds of rutile and ilmenite with rutile described here, an interesting microscopic structure was observed which is displayed by the formation of usually rather thick ilmenite envelope about the skeleton-like rutile core. Fine-flaked hematite is very often separated from rutile, the hematite being gradually attached to the extensions of ilmenite penetrating into the rutile core. Ilmenite predominates over rutile in a great majority of cases investigated. On the basis of the comparative material it was found that an analogous or at least very similar internal structure occurs in most pebbles considered by various authors to be rutile, ilmenite, nigrine or iserine.

Roentgenometric investigation of the material from surface parts of the pebbles, containing a predominance of ilmenite, has revealed a good agreement of the data obtained with those found in the standard tables for ilmenite. Only ilmenite from Bražná displays rather marked deviations from these values which can be ascribed to the presence of rutile and separated hematite which are most likely to play a role here.

It was shown by a detailed investigation of the pebbles and of thin sections of the mother rocks that the accumulation of ilmenite grains about rutile will represent a rather common phenomenon in some metamorphic rocks, especially in amphibolites and hornstones.

The results obtained point quite clearly to the necessity of further and more extensive research of rutile and ilmenite pebbles from deposits and of their occurrence in the mother rocks which would then unequivocally demonstrate their origin, composition and possibly also transformations.

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EXPLANATION TO THE TABLES

TAB. XXXV. The Debye-Scherrer diagrams of rutile and ilmenite (Respective laboratory conditions are published in the text)

1. Rutile from Lasur hill near Michalovy Hory (inv. no. 42,498)
2. Rutile from Podmoky near Čáslav (inv. no. 34,799)
3. Ilmenite from Cyrilov near Velké Meziříčí (inv. no. 33,675)
4. Ilmenite from Moravany near Čáslav (inv. no. 33,251)
5. Ilmenite from Putim near Písek (inv. no. 34,011)
6. Ilmenite from Bražná near Kamýk on Vltava (inv. no. 33,619)

TAB. XXXVI. a) Rutile from Podmoky near Čáslav (inv. no. 34,799, nat. size 12 × 8 cm. Photo J. Slavíková, National Museum in Prague)

b) Rutile from Moravany near Čáslav (inv. no. 33,251, nat. size. Photo J. Slavíková, National Museum in Prague)

TAB. XXXVII. Microphotographs of rutile with ilmenite from Bražná (inv. no. 33,619)

1. Section cut approximately perpendicular to the c axis (Magnification 16 ×)
2. Section cut parallel to the c axis with interposed twinning lamella
3. Section cut parallel to the c axis with lenticular forms of ilmenite (Magnification 16 ×)
4. The same section between crossed nicols (Photo J. Slavíková a dr. V. Šípek)

TAB. XXXVIII. Granular rutile in amphibolite with garnet from Cyrilov near Horní Bory, Moravia (Department of Mineralogy and Petrography of the Moravian Museum in Brno; nat. size 7 × 4 cm. Photo J. Slavíková National Museum, Prague).

Table 1.

Results of spectral quantitative analyses.

	Rutile		Ilmenite							
	11.532 Bamle, Norway	34.799 Podmoky, Bohemia	22.045 Krageroe, Norway	33 675 Cyrilov, Moravia	34.010 Putim, Bohemia	33.619 Bražná, Bohemia	22.050 Ilmen Mountain, USSR	11.497 Malonice, (nigrine) Bohemia	22.003 Jiz. Louka, (iserine) Bohemia	24 828 Tefina, (ilmenorutil) Madagascar
I. Essential (above 1%)	Ti	Ti	Fe Ti	Fe Ti	Fe Ti	Fe Ti	Fe Ti	Fe Ti	Fe Ti	Fe Ti
II. Subordinate (1—0.1%)	Ca		Mg Al Si	Mg Mn	Mg Mn	Mg Mn Ca			Mg Ca	Ta Ca
III. Insignificant (0.1—0.01%)	Fe	Fe Mg Ca	V Ca	Sn Ca	Sn Ca	Sn	Mg Mn Ca	Mg Mn Ca	Mn Al	Sn
IV. Traces (less than 0.01%)	Mg	V		V Nb					Sn	Mg Mn

Table 2.

Roentgenometric data on rutile

Michejev 146; 266		Hanawalt		Hanawalt II - 3432		Inv. no. 34.799		Inv. no. 42.496	
Rutile, Semiz-Bugu		Rutile II - 1089		Ilmenorutile, Ilmen Mountain		Rutile, Podmoky		Rutile, Michalovy Hory	
d	I	d	I	d	I	d	I	d	I
(3.598)	3								
3.242	9	3.24	1.0	3.269	.7				
						3.218	3	2.98	3
(2.750)	1					2.813	2dif	2.67	5
						2.46	3	2.52	1
2.488	8	2.49	.7	2.497	.5	2.47(?)	3	2.42	3
2.294	2	2.26	.3K	2.305	.1			2.34	2
2.189	7	2.19	.4	2.185	.1	2.17	3	2.17	2
2.053	3	2.05	.3			2.05	1	1.93	5
(1.870)	4	1.877	.4B					1.88	1
(1.800)	2	1.779	.2dB					1.72	2
1.689	10	1.682	1.0	1.695	1.0	1.689	5	1.65	4
1.624	8	1.622	.6n	1.626	.5	1.61	2	1.60	7
1.537	1	1.500	.2K					1.49	3
1.482	3	1.470	.2n	1.483	.1	1.48	1		
1.453	4	1.450	.4n	1.456	.3	1.449	2		
1.362	6	1.357	.8	1.368	.3				
1.347	3			1.360	.1	1.363	3		
		1.338	.7C			1.341	2	1.336	3
		1.306	.2C					1.301	4
		1.260	.$^1/_2$K					1.271	3
		1.238	.4n			1.237	1		
		1.194	.2C					1.208	2
1.169	2	1 163	.5n			1.166	3	1.165	1
1.149	2	1.141	.4C			1.142	1		
		1 103	.2C					1.106	5
1.093	4	1.095	.4n			1.090	3	1.088	5
1.082	2	1.077	.5C			1.076	2		
1.041	5	1.041	.5n	1.047	.5			1.053	3
						1.039	3		
		1.031	.6C			1.0319	3		
		1.022	.5C			1.020	2	1.015	1
								0.993	3
								0.9801	3
						0.960	2	0.967	8
0.963	3								
								0.9274	1
				0.895	.3			0.9016	3
				0.881	.3			0.8998	1

Table 3. Roentgenometric data on ilmenite

Hanawalt II - 1842		Torre-Garrido No.91, p.91		Michejev 169; 244		Inv. no. 34.011		Inv. no. 33.251		Inv. no. 33.675		Inv. no. 33.619	
Ilmenite, Egersund, Norway		Ilmenite (Hanawalt)		Ilmenite, Quincy, Mass., USA		Ilmenite, Putim, Bohemia		Ilmenite, Moravany, Bohemia		Ilmenite, Cyrilov, Moravia		Ilmenite, Bražná, Bohemia	
d	I	d	I	d	I	d	I	d	I	d	I	d	I
4.5	.1P			4.5	1								
3.70	.4P	3.70	3	3.70	4			3.74	2				
								2.81	1				
2.73	1.0	2.73	1	2.74	10	2.72	7	2.74	5	2.75	2	2.78	3
								2.59	1				
2.53	.9	2.53	8	2.53	9	2.52	3	2.53	5	2.53	2	2.57	2
2.23	(.3P			2.23	3	2.21	3	2.24	2	2.24	1	2.27	1
	(.7H	2.218	3										
2.03	1.0H	1.890	1										
1.86	.6	1.854	4	1.865	6	1.85	3	1.88	3	1.87	2	1.88	2
1.718	.8	1.716	8	1.720	8	1.72	7	1.71	5	1.72	4	1.75	5
1.62	.3	1.625	1	1.63	3	1.62	2	1.64	2	1.64	1	1.65	1
1.501	(.7P	1.498	6	1.504	7	1.493	5	1.50	3	1.50	2	1.52	3
	(.3H												
1.461	(.7P	1.462	6	1.465	7	1.453	5	1.469	3	1.47	3	1.48	2
	(.3H												
1.375	.2P			1.375	2								
1.347	.1P	1.335	3	1.347	1	1.333	5	1.339	3	1.339	1	1.349	3
1.326	.2H												
1.270	.3P	1.267	2	1.270	3	1.262	2	1.278	1				
1.242	.1P			1.242	1								
1.205	.2P			1.205	2	1.200	2	1.213	1				
1.185	.2P			1.185	2	1.178		1.185	2				
							3					1.160	2
1.147	.2P			1.147	2	1.148	5	1.155	3	1.155	2		
1.111	.2P			1.111	2	1.111	5	1.118	3	1.115	2	1.120	3
1.069	.3P			1.069	3	1.070	5	1.073	5	1.072	3	1.078	5
1.050	.1P			1.050	1			1.05	2	1.048	1	1.053	1
1.000	.2P			1 000	2			1.01	1	1.000	2	1.003	2

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V srpnu 1960 vydalo svým nákladem v počtu 800 výtisků Národní museum v Praze.

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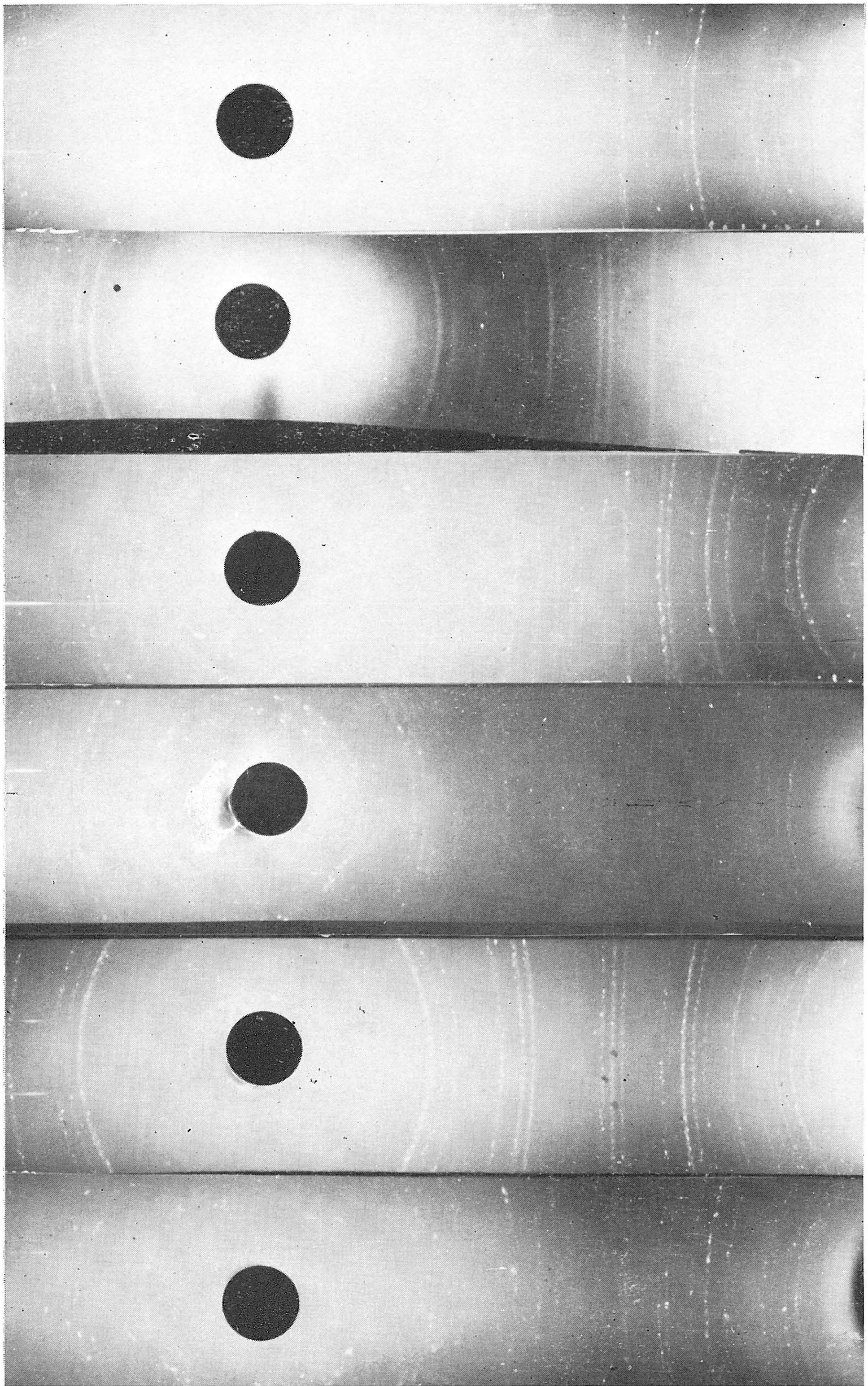

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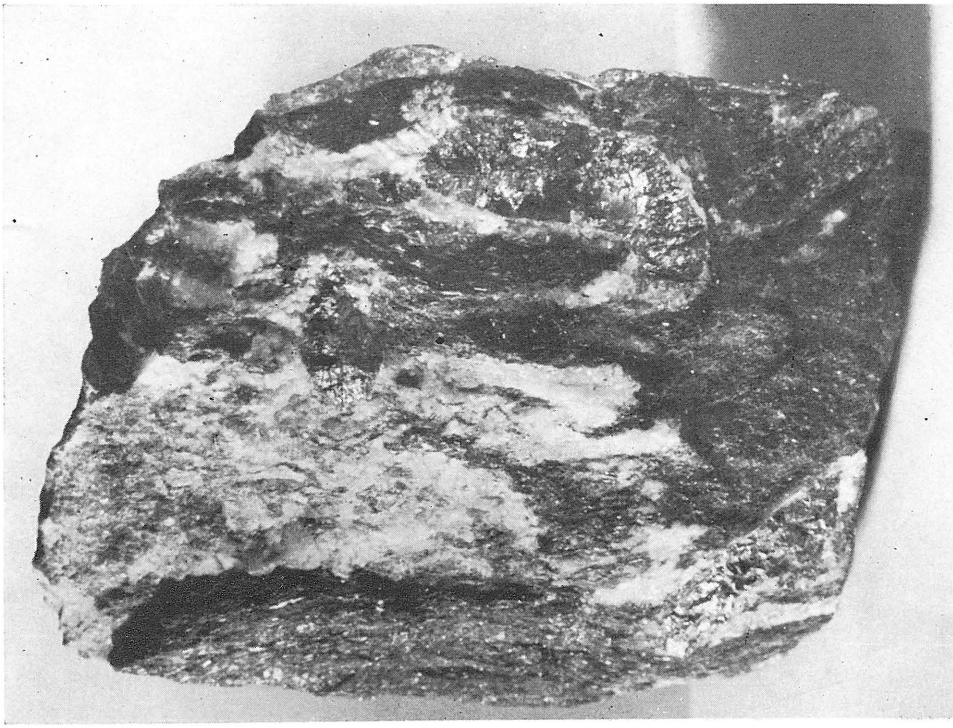

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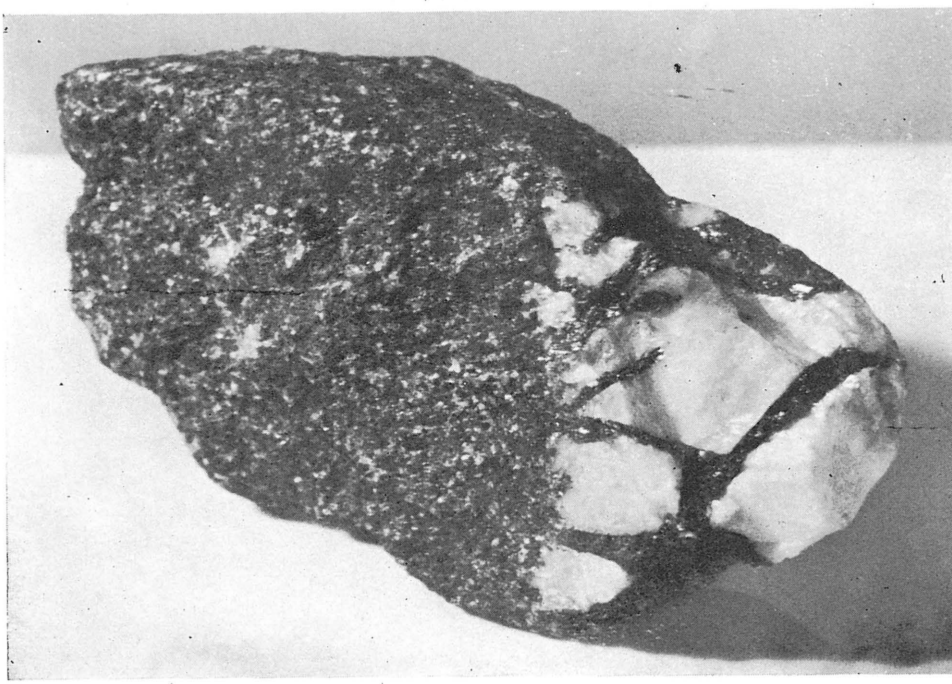

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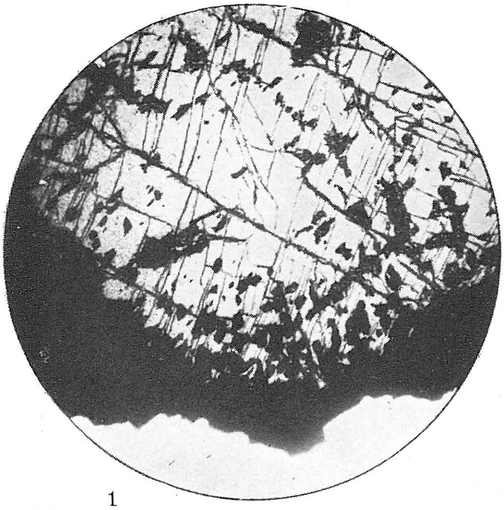

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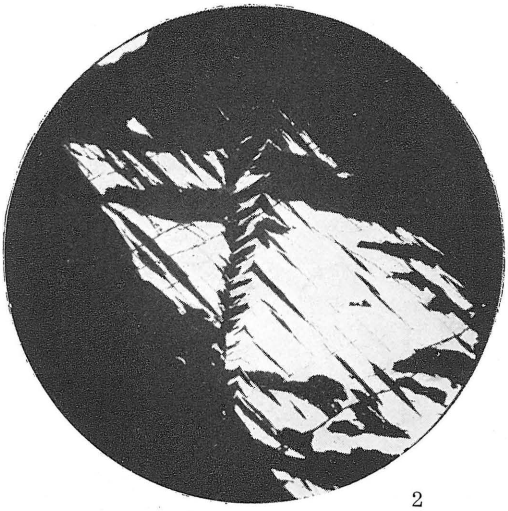

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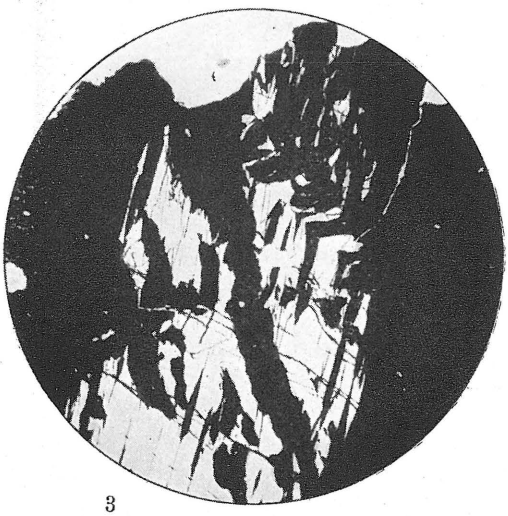

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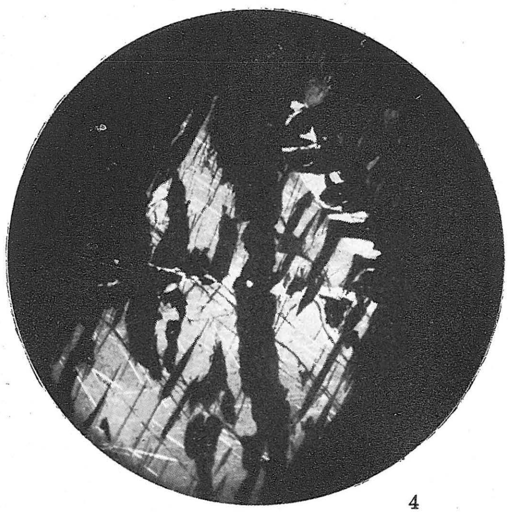

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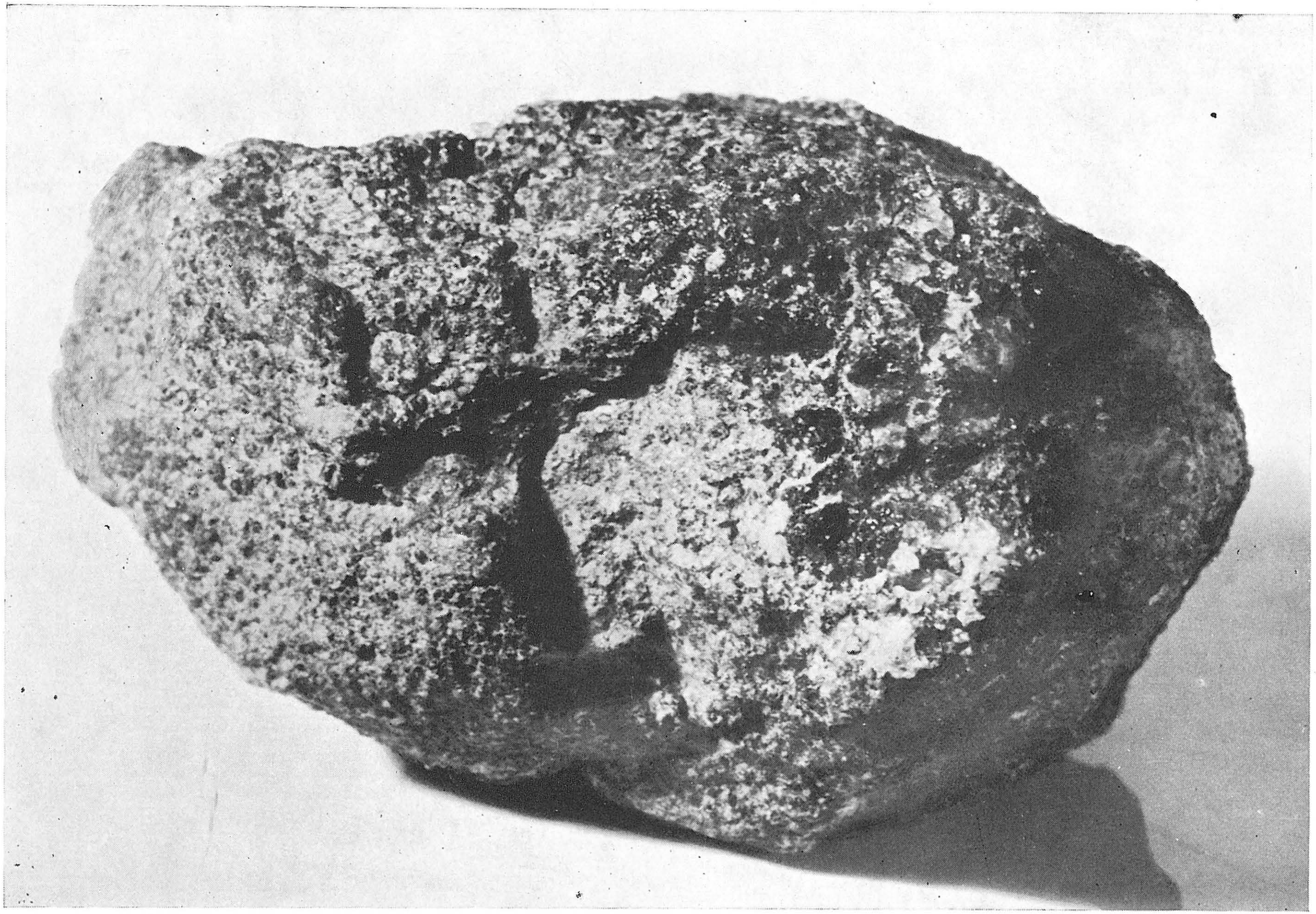

Granular rutile in amphibolite with garnet. Cyrilov near Horní Bory, Moravia, Czechoslovakia. Prof. J. Slavíková