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# Origin and age of Izera gneisses and Rumburk granites in the Western Sudetes

ABSTRACT: The present study concerns petrological, geochemical and geochronological relations between the Rumburk granite and the Izera gneisses in the Western Sudetes. It has been demonstrated that the Izera gneisses are orthoderived; they form, with the granites, a plutonic anorogenic coherent complex of alkaline character. This complex has been affected by a regional Variscan metamorphism dated as post-Famennian and before 320—310 Myr. Its emplacement between 500 and 450 Myr ago extends eastwards the evidence of riftogenic processes in the Lower Paleozoic of Europe.

## INTRODUCTION

The Izera gneisses constitute the crystalline basement and are the main component of the Karkonosze-Izera block in the Western Sudetes. In the north-east they are covered with the schists of the Kaczawa Mts, to the west they pass into the East-Lusatian granodiorites (called Zawidów granodiorites) and Rumburk granites, and to the south they are bordered by the late-Variscan intrusion of the Karkonosze granite.

The origin of the gneisses, their age and evolution have been variously interpreted in the geological literature. Most authors agree that there is a close affinity between the Izera gneisses and the East-Lusatian granitoids. In the older papers the gneisses have been considered as of magmatic origin. Some of the authors (Berg 1922, Bederke 1939, Schwarzbach 1943) were of the opinion that the gneisses represent a synkinematic instrusion; others (Rimann 1910, Ahrens 1926, Ebert 1943, Watznauer 1955) regarded them as orthogneisses deriving from the Rumburk granite. More recent investigations (Kozłowska-Koch 1960, 1965; Oberc 1961; Szałamacha & Szałamacha 1964) have led to the conclusion that the Izera gneisses, at least in the major part, resulted from metasomatic transformation of the Precambrian supracrustal series, the Rumburk granite being the final effect of this process (Oberc 1961).

There are various hypotheses concerning the age of the source material of the gneisses. Some authors (Oberc 1961; Teisseyre 1962, 1968; v. Gaertner 1964; Kozłowska-Koch 1965; Szałamacha 1970) consider this material as of Precambrian age, others (Brüll 1942; Murawski 1943; Chaloupsky 1963) give a pre-Ordovician-Silurian age. Bederke (1956) is of the opinion that the gneisses are the product of Caledonian palingenesis of Precambrian granites.

The evolution stages of the gneisses have also been variously dated. However, Gorczyca-Skała (1966) has shown that structural features in the Izera gneisses and Kaczawa schists are very similar as had already been suggested. In this context, the age of the sedimentation of the Kaczawa schists is of fundamental importance in the dating of the structural evolution of Izera gneisses.

According to current views, there appear the following stratigraphical formations among the Kaczawa schists:

- Upper-Proterozoic Lusatian greywackes;
- Eocambrian formations;
- Cambrian assigned by paleontological evidence at Zgorzelec, afterwards paleontologically confirmed at Wojcieszów (Gorczyca-Skała 1966, Gunia 1967);
- Ordovician formations, paleontologically dated in the northern part of the Kaczawa Mts (Baranowski & Urbanek 1972, Urbanek 1974), in the southern part demonstrated on the basis of facies resemblance. The greywackes and arkoses containing detrital feldspars derived from the Rumburk granites were assigned to the Ordovician (Brüll 1942). Similar rocks in the vicinity of Lubań are considered by Brause (1965) as late-Devonian;
- Silurian formations, well evidenced by graptolites in the vicinity of Lubań;
- Devonian, recognized on the basis of conodonts in the northern part of the region (Urbanek & al. 1975; Urbanek 1974, 1978) and on the basis of graptolites in the vicinity of Lubań (Jaeger 1964);
- Carboniferous (Viséan) formations, where recent paleontological evidence (Chorowska 1977) has confirmed the previous prediction of Schwarzbach (1936, 1939).

Recent important paleontological findings enable us to reconstruct the whole stratigraphic sequence of the rocks subject to metamorphic transformations. These findings point to a much younger age of the Karkonosze-Izera block than usually assumed. Of specific importance is the statement by Urbanek (1978) that the geosynclinal sedimentation had not ceased before the end of the Famennian. From this statement it appears clearly that the metamorphism of the Izera gneiss complex and the Kaczawa series could not have taken place before the Carboniferous period.

## SHORT DESCRIPTION OF LITHOLOGIES

The Izera gneisses and the Rumburk granites constitute a cartographically coherent complex over an area of about 1,500 km². Their most recent detailed description has been made by W. Smulikowski (1972). In this paper we will therefore limit ourselves to a general description of rocks resampled for geochemical studies and radiometric age determination. The sketch map (Text-fig. 1), showing relations between the main geological formations also indicates our sampling localities.

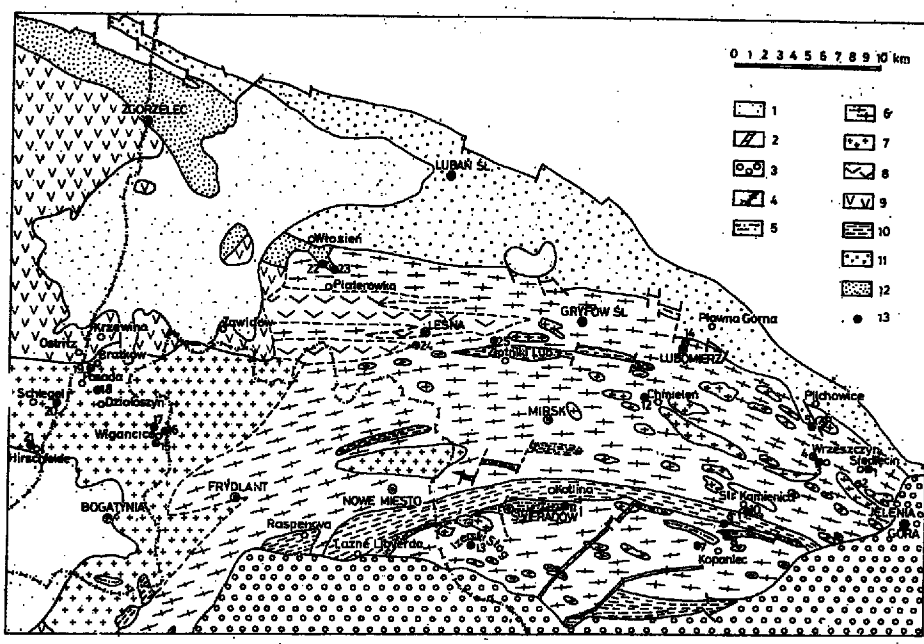


Fig. 1. Geological sketchmap of the northern cover of the Karkonosze granite in the Western Sudetes (*after* W. Smulikowski 1972, modified)
**1** — Tertiary formations, **2** — dike-rock (microgranite), **3** — Karkonosze granite, **4** — vein of the Izera quartz, **5** — leucogneisses and leucogranites, **6** — Izera gneisses (typical), **7** — Rumburk granites, **8** — granodioritic gneisses, **9** — Zawidów granodiorites, **10** — mica-schists of the Izera complex, **11** — phyllites and schists of the Kaczawa Mts, **12** — "Lusatian greywackes", **13** — sampling localities

Among the Izera gneisses, three essential varieties can be distinguished: (*1*) granodioritic gneisses, which are not taken into account here and which are contigous to the East-Lusatian granodiorites, showing a great similarity to them, (*2*) typical Izera gneisses, (*3*) leucocratic gneisses.

The typical Izera gneisses constitute a complex of very variable megascopic appearance. One can distinguish among them light coarse-grained and porphyroid granitoids with big feldspar phenocrysts, light lenticular gneisses, darker medium-grained granites, light gneisses very rich in disseminated biotite crystals locally forming bigger aggregates, and fine-grained, laminated gneisses (lighter and darker) with isolated feldspar and quartz phenocrysts.

Under the microscope these rocks most often show uneven-grained textures and oriented structures. Some of them show a distinct foliation which is locally caused by the cataclasis (Pl. 1, Fig. 1). Textures are rarely typically hipidiomorphic-granular with unoriented structures, as in true granites. The potassium feldspar is spotted or cross-twinned microcline, often perthitic, sometimes cut by tiny fissures filled with feldspar-quartz mosaic (Pl. 2, Fig. 1). In some places the K-feldspar appears as big phenoclasts surrounded by a border of finely granular feldspar and quartz fragments (Pl. 1, Fig. 2). The microcline perthite is locally transformed to chessboard-albite. The obliquity of the K-feldspars is intermediate to high (conventional triclinicity = 50—100%). The crystals of plagioclase (oligoclase or albite) are sometimes zoned, often filled with sericite and zoisite. Albite most often occurs in rocks where the K-feldspar has been partly transformed to chessboard albite. In the rims of feldspar grains, myrmekite locally appears. Quartz forms big crystals (partially idiomorphic) as well as fine grains composing, together with feldspar grains, a fine-granular mosaic.

Biotites predominate amongst micas in most rocks; their crystals contain numerous inclusions of apatite, zircon, iron oxides and leucoxene. The biotite is often chloritized and rich in pleochroic haloes. In the rocks intensively gneissified it has been completely replaced by chlorite. Muscovite, normally subordinate, predominates in strongly foliated laminae of the gneisses. In the tectonically affected gneisses occurring on the contact with the Kaczawa schists, the white mica appears as phengite forming strips composed of deformed little plates wih spotted extinction; it also forms pseudomorphs after cyanite, accompanied by leucoxene. Rare, undeformed poeciloblasts of garnet are sporadically distributed in the gneisses.

Calcite occurs in feldspars, in the fine-grained quartz mosaic and fills small fissures cutting the gneisses. Sphene and pyrite occur in some gneisses as accessory minerals in addition to apatite and zircon. Pyrite is partly oxidized, accumulated on the rims and in the cores of sphene, or occurs as little inclusions in chlorite. Sagenite net can be observed in some chlorites. Some gneisses contain pinite aggregates, most often pale green in colour.

Aplites, locally cutting the gneisses, are very light in colour and very fine--grained. Their texture is microporphyric. In the feldspar-quartz rock-mass there occur phenocrysts of microcline with spotty or cross-hatched extinction and phenocrysts of plagioclase, sometimes idiomorphic. In the groundmass, faint bands of very fine-grained feldspar mosaic are observable and very small plates of white mica are disseminated. Minute amounts of black iron oxides and zircon can be seen in the rock.

Hololeucocratic types of the gneisses (leucogneisses and leucogranites) are megascopically light and medium-grained and reveal unequigranular textures and a more or less parallel disposition of minerals under the microscope. The cross--twinned microcline (microcline maximum) occurring in the largest crystals is perthitic and locally passes into chessboard-albite. It is often cut by thin fissures with fine-grained albite or albite and quartz. Plagioclase, which occurs in smaller crystals than those of microcline, is albite without inclusions. The fine-grained feldspar-quartz mosaic, in which lenticular aggregates of a more coarse-grained quartz occur, fills the spaces between the big feldspar crystals in the leucogneisses. This mosaic is absent in the leucogranites. Micas are rather rare, occurring in some rocks in trace amounts. Muscovite predominates: flakes and elongated tiny laths join in thin bands surrounding the little feldspar augen or cluster with sericite and small feldspar grains between the bigger crystals. Microcline in small grains is always pure and non-perthitic. The olive-brown, and always at least partly chloritized biotite is rich in pleochroic haloes encircling small inclusions of zircon and probably other radioactive minerals indeterminable under the miscroscope. The hololeucocratic rocks sometimes contain green bluish tourmaline occurring in small crystals mostly in clusters among mica aggregates. Apatite, leucoxene, haematite, magnetite and fluorite are accessory. The gneisses have been locally deformed; the plagioclase twin lamellae being curved in some places.

The Rumburk granites, mostly light and coarse-grained with big crystals of potassium feldspar (2.5—4 cm diameter), are very similar to some Izera gneisses. Their texture is hipidiomorphic-granular, and their structure practically isotropic unordered (Pl. 3, Fig. 1). In some places a slightly marked fabric can be observed. Quartz in big crystals is partly idiomorphic. Microcline perthites (100% conventional triclinicity) locally pass into chessboard albite. Plagioclases (oligoclase or albite) are often sericitized. Micas are represented by biotite and muscovite or by muscovite alone. Biotite, brown-red or dark brown, is corroded locally and its plates are generally concentrated into isolated clusters (Pl. 3, Fig. 2). These clusters are developed during secondary recrystallization of large primary phenocrysts. Intensive pleochroic haloes surround zircon inclusions. Apatite and magnetite also often occur here as inclusions. The chloritized parts contain sagenite and leucoxene. Muscoflakes being often recrystallized sericite. In some places, pinite pseudovite in bigger plates has a spotty extinction; the muscovite in small morphs after cordierite (the relics of which are sometimes preserved) are visible.

Aplitic, fine-grained parts of the granite reveal under the microscope an unequigranual texture, the presence of microcline and orthoclase, plagioclase $An_{10}$ and muscovite with spotty extinction. Little patches, visible macroscopically, are aggregates of sericite flakes among which appear: muscovite, leucoxene, magnetite, haematite, chlorite after biotite and tourmaline in small crystals.

Generally, one can say that the Rumburk granites, although not showing the foliation or fine-grained feldspar-quartz mosaic of the Izera gneisses, nevertheless very much resemble these gneisses in their composition and in the habit of the main minerals, especially the feldspars (Pl. 2, Figs 1—2). The big crystals of K-feldspar in many Izera gneisses and the microcline of the Rumburk granites are identical not only in the manner of cross-twinning and in the type of perthitic intergrowths but also in the manner of passing into the chessboard albite. Plagioclases are similar too. Pinite, often occurring in the Rumburk granites, is also sometimes met with in the Izera gneisses, although without preserved relics of cordierite.

There is no distinct limit between the Rumburk granites and the Izera gneisses, the transition being gradual. In the gneisses the foliation is very irregularly marked, its intensity decreasing from east to west. Mega-mesoscopic gneissic lamellae are observed in the western part of the complex, whereas lenses of undeformed granite can be mapped in the east. The intensity of the foliation is also unequally distributed on the scale of one outcrop. This fact may be interpreted in two ways: either the foliation has been acquired by the granites (orthogneisses) or the foliation is residual (metasomatic origin of the Rumburk granites). Our observations incline us to the first hypothesis.

In some places, especially on the northern border of the Izera gneiss complex, one can observe gneissified rocks which show undoubted sedimentary origin. They reveal blastopsamitic textures and contain detrital feldspars.

## RELATIONS OF THE IZERA GNEISSES TO THE ADJACENT FORMATIONS

Knowledge of the relations between the Izera gneisses and the adjacent rocks is important for understanding the problems concerning the origin of the gneisses. Since the last descriptions were interpreted in a metasomatic model, we have tried to reexamine the facts.

### THE INTRUSIVE CONTACT

The contact of the Izera gneisses with the adjacent rocks was reexamined at Platerówka (point *23* in Text-fig. 1), at the place precisely described by W. Smulikowski (1972). It is a sharp, slightly sinuous contact of an alkali-feldspar granite with a fine-grained greywacke embedded in the form of a roof pendant in the granite. In the granite, the rhyolitic form of quartz grains and micropegmatitic textures (Pl. 4, Fig. 1), are evidence of rapid cooling compatible with the proximity of an intrusive contact. In the greywackes, evidence of recrystallization indicating the presence of intrusion is lacking. However, such evidence could be hardly expected in rocks very rich in feldspars and poor in pelitic components. A later deformation led to the formation of an irregularly penetrative schistosity which cuts the contact. On the thin section scale, this schistosity is shown by a cataclasis concentrated in the microshear zones; this cataclasis is, however, not sufficient to mask primary structural features. The deformation is accompanied by a metamorphic recrystallization forming some muscovite and welding together the grains broken or eroded by the cataclasis.

### EVIDENCE OF THERMAL METAMORPHISM

In the vicinity of Kotlina, near the contact of the schists with the hololeucocratic gneisses, we have examined the rocks called "leptinites" by Kozłowski (1966). These rocks belong to a large schist zone forming a narrow band elongated in W-E direction parallel with the foliation of the gneisses and mainly composed of garnet bearing micaschists very rich in sheet minerals. In the vicinity of Kotlina, the "leptinites" are fine-grained, light-coloured and laminated rocks alternating with layers enriched in micas and containing garnet. The presence of phenocrysts of biotite gives to the "leptinites" a peculiar spotted appearance.

The existence of the biotite phenocrysts in the proximity of the hololeucocratic varieties of the gneisses was interpreted as indicative of metasomatic activity in this region (K. Smulikowski 1958; Kozłowski 1966, 1974; W. Smulikowski 1972). Our observations lead to another interpretation. The phenoblasts are poecilitic. The inclusions they contain retain a planar structure. The plane (001) of the biotite phenocrysts is not parallel either with the present foliation or with the plane preserved by the inclusions. The biotites also do not show a regular orientation in relation to each other. The phenoblasts are deformed by the foliation which is therefore younger (Pl. 4, Fig. 2). The phenoblasts do not, however, show any more trace of torsion than any of the other minerals of the rock, so the recrystallization of these minerals was late- or post-kinematic. This fact is particularly illustrated by the garnet (Pl. 5, Fig. 1) which is so poeciloblastic as to be spongy. The garnet is not helicitic but *"à l'emporte-pièce"* as it was in the gneisses. In their present state, the big biotite crystals are the result of a mimetic restoration of the phenoblasts.

It seems without any doubt that, in these materials of sedimentary origin, the development of the big biotite crystals is due to a common thermal contact metamorphism caused by the proximity of the granite which was later transformed into the Izera gneisses.

Deformation and recrystallization during the development of foliation affected both the granites as well as their cover (to which also belong all or part of the schists of the zone of Kotlina). The present banding is therefore a stratification largely replaced by the foliation which corresponds here to a strong fabric as distinct from that observed in Platerówka.

The gneissification was independent of the emplacement of the granites and is distinguished by a fabric which varies in intensity from place to place. The gneisses are therefore orthogneisses.

## TRANSGRESSIVE CONTACTS

The section of the left side of the river Bóbr by the Pilchowice dam (point 5 in Text-fig. 1) represents this type of contact. Foliation and banding which are parallel, dip ∾30° to the north. The Kaczawa series lies on the gneisses.

Approaching the contact, the gneisses do not show any observable variability of lithology until some dozen meters distant from the contact. Here they become lighter in colour, their grain size being fine, more regular, and their schistosity more compact. On the top, the light facies is suddenly replaced by chlorite micaschists after which ocelar prasinites appear (Pl. 5, Fig. 2).

As shown in microscopic observations, the light facies is composed mainly of quartz and alkali feldspar (Pl. 6, Fig. 1). This feldspar is identical with the feldspar of typical gneisses due to the presence of the perthitic spotty albite (Pl. 6, Fig. 2). Its grains are not very big, and phenocrysts are lacking. The manner of arrangement of the grains cannot be explained by granulation. Some polycrystalline grains have the features of detrital origin. Moreover, it is significant that the plagioclases exist here in the form of inclusions in the alkali feldspars (Pl. 6, Fig. 2). Albite, instead, is present in perthitic patches, on the rims of detrital feldspar grains and (in small amounts) in the rock matrix beside the quartz grains. The growth of the albite during metamorphism was accompanied by recrystallization of quartz and muscovite and microclinization of alkali feldspar.

These facts led us to interpret the light and fine-grained gneisses occurring directly under the chlorite micaschists as more or less transformed primary arkoses (immature alluvium). The origin of these arkoses could be related to the porphyroid granites which are protoliths for most of the Izera orthogneisses. The sedimentary differentiation has caused, through partial weathering of the granites, a dissemination of the plagioclases and biotites in the metaarkoses which have given fine-grained light gneisses.

The passage to the transgressive area (chlorite micaschists, afterwards prasinites) is abrupt and contrasting. However, in the first micaschist horizon, some detrital fragments of potassium feldspar characterized by perthite patches can still be observed. It is on the basis of these feldspars that the concept of metasomatic development of the Izera gneisses (W. Smulikowski 1966), or of an intrusive contact of the gneisses with the Kaczawa series connected with a metamorphism of the Kaczawa schists (Schmuck 1957), has been founded. Our studies seem to indicate, however, that synmetamorphic potassium feldspar is very rare and shows the features of a low-temperature microcline, optically homogeneous and devoid of perthitic albite. We are therefore dealing with sediments transgressively lying upon the porphyroid granite, in areas showing a poorly differentiated relief; evidence of this being the mainly fine pelitic sediments.

The study of the contacts of the Izera gneisses with the adjacent rocks, through not exhaustive, has led to the following conclusions:
*1*) All or part of the Izera gneisses were derived from a granitic complex;
*2*) The adjacent formations are partially pre-intrusive, in the remaining part transgressive;
*3*) The whole has been transformed by a regional tectonometamorphism.

The aim of the subsequent chapters is to characterize the granitic complex under discussion by means of major element geochemistry and the geochemistry of strontium isotopes, then to determine the age of the emplacement of the pluton by means of the whole-rock Rb/Sr method and the age of the last thermal event by means of the same method applied to the minerals. The isotope geochemistry should also help to further our knowledge of the origin of the sialic crust in the studied crustal segment of the Central European Hercynides.

## GEOCHEMICAL CHARACTERISTICS OF THE RUMBURK GRANITE AND THE IZERA GNEISSES

A geochemical study has been undertaken with the aim of: (*1*) elucidating the origin of the Izera gneisses, (*2*) determining if the Izera gneisses and the Rumburk granites have common geochemical characteristics and, if so, (*3*) checking the hypothesis of their common evolutionary history.

Nine samples of Rumburk granite, 20 of the Izera gneisses (including 1 aplite) and 6 of their hololeucocratic types were analysed (granodiorites and granodioritic gneisses were excluded from the study).

To distinguish between an eventual sedimentary or magmatic origin for the gneisses, the diagram proposed by Tarney (1976) has been used. This author has shown that magmatic acid rocks and rocks of sedimentary origin define, on the diagram $TiO_2$ vs $SiO_2$, two different fields separated by a straight line of negative slope. The Izera gneisses and the Rumburk granites fall into the field of magmatic rocks (Text-fig. 2). Though the border line between these two fields is not precisely defined,

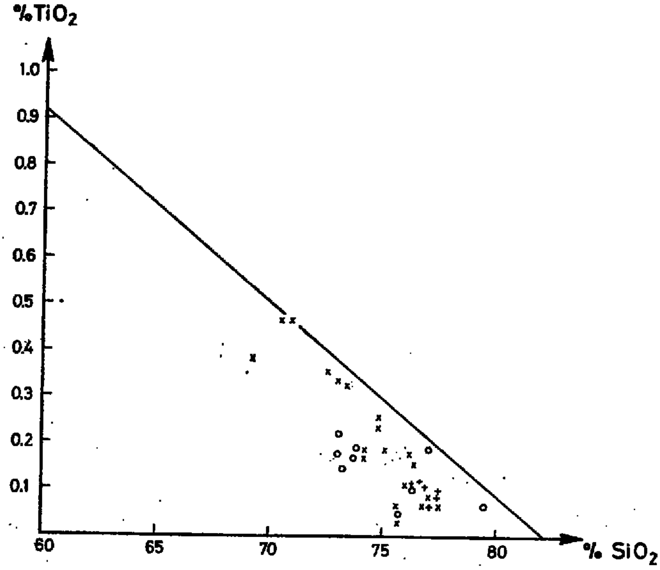


Fig. 2. Tarney's diagram with diagonal line separating magmatic acid rocks from rocks of sedimentary origin: X — typical Izera gneisses; O — Rumburk granites; + — leucogneisses and leucogranites

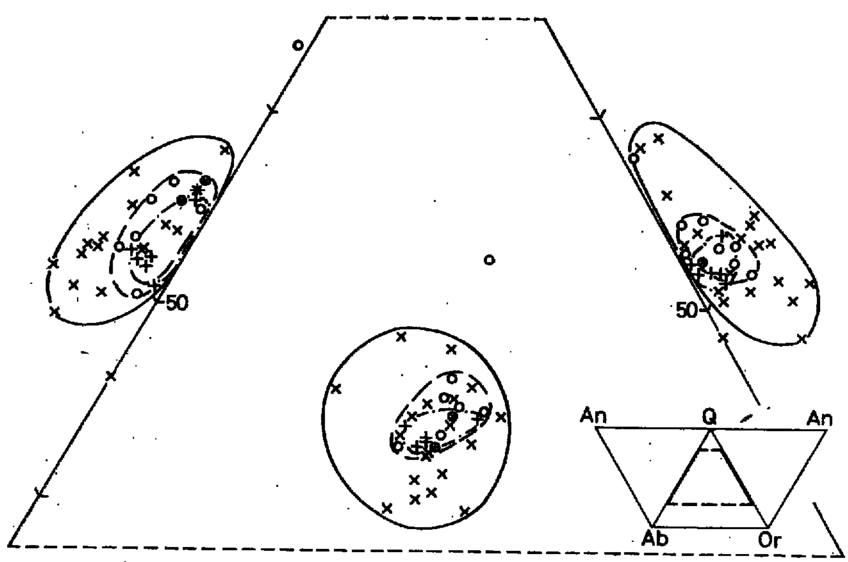


Fig. 3. Distribution of the points representing typical Izera gneisses (X), Rumburk granites (O) and leucogneisses (+) in the triangle diagrams Q-Or-Ab, Q-Ab-An, Q-Or-An. The deviated points represent cataclased and altered granite No. *20* and the aplite No. *6b* (*see* Tables 1 & 2)

we are inclined to consider the obtained data (distribution of the points) as indicating a magmatic origin for the Izera gneisses.

The triangular diagrams (Text-fig. 3), on which the normative values of Q-Ab-Or-An (*see* Tables 1—3) calculated from chemical analyses of the Rumburk granite and of the Izera gneisses are represented, demonstrate that the points of the Rumburk granite belong to the same field of compositions as the Izera gneisses. In the triangle Q-Ab-Or, this field is situated around the mean eutectic position. Only point 20 corresponds to a granite abnormally rich in quartz; this granite is, however, relatively cataclased and altered. In the triangle Q-Ab-An, the field of all the compositions is situated near the side Q-Ab, so expressing the alkaline character of these rocks. In this triangle, the granites of Rumburk are not so well contained within the field of the Izera gneisses as in the Q-Ab-Or triangle; this is caused by the fact that the quartz-poorer varieties of the gneisses are simultaneously richer in anorthite component and manifest therefore, in comparison with the granites of Rumburk, a slight calc-alkaline tendency. In these respects, the Rumburk granites cover a part of the compositional range of the Izera gneisses. The hololeucocratic varieties of the Izera gneisses correspond to a much more homogenous assemblage and are distinctly alkaline.

In the $Al_2O_3$ vs $SiO_2$, $\Sigma$ Fe vs $SiO_2$, and MgO vs $SiO_2$ diagrams (Text-fig. 4) the "normal trends" are obtained. The hololeucocratic gneisses occupy the extreme limit of the trend. The CaO vs $SiO_2$

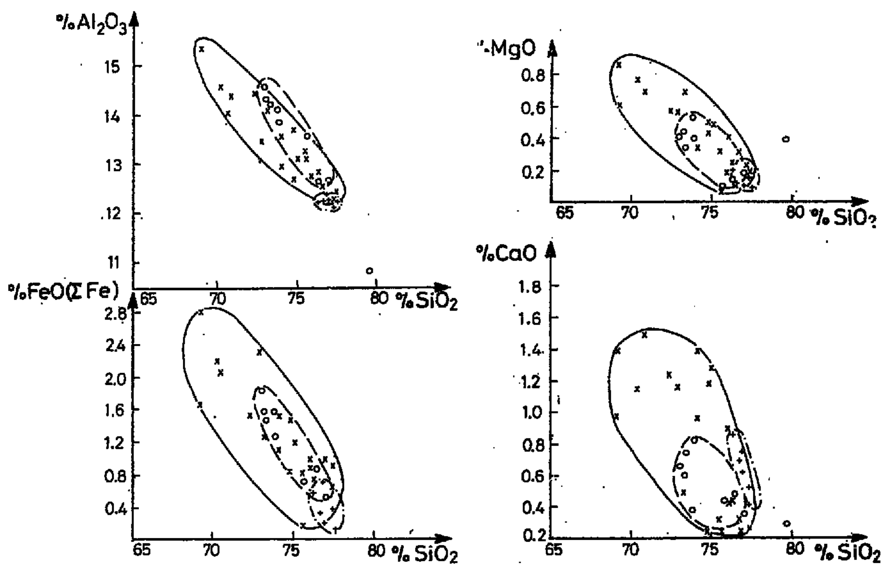


Fig. 4. Harker's diagrams $Al_2O_3/SiO_2$, $FeO/SiO_2$, $MgO/SiO_2$, $CaO/SiO_2$ for Izera gneisses (X), Rumburk granites (O) and leucogneisses (+). The deviated point represents cataclased granite No. *20*

diagram shows a larger ellipse. The $Sr/SiO_2$ diagram (Text-fig. 6) possesses the same features but with a more extended field for the leucogneisses. It is worth noting that $K_2O$, $Na_2O$ and Rb versus $SiO_2$ diagrams (Text-figs 5—6) show a lack of negative correlation both for the granites and for the gneisses. Furthermore, all the diagrams show that the Rumburk granites are situated inside the field of the Izera gneisses; in addition, the trends of the two groups are the same. The

Table 1

Chemical analyses of Rumburk granites (weight %)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| No. of the sample | 16 | 17 | 18 | 19 | 20 | 21 | 15 | 17b | 32* |
| $SiO_2$ | 75.67 | 73.81 | 76.98 | 76.35 | 79.51 | 73.75 | 73.22 | 73.02 | 73.22 |
| $TiO_2$ | 0.05 | 0.19 | 0.19 | 0.10 | 0.07 | 0.17 | 0.15 | 0.18 | 0.24 |
| $Al_2O_3$ | 13.35 | 13.84 | 12.62 | 12.62 | 10.79 | 14.10 | 14.26 | 14.52 | 14.35 |
| $Fe_2O_3$ | 0.03 | 0.01 | 0.21 | 0.52 | 0.56 | 1.06 | 0.77 | 0.59 | 0.63 |
| FeO | 0.70 | 1.29 | 0.35 | 0.41 | 0.66 | 0.65 | 0.89 | 1.32 | 0.83 |
| MnO | 0.03 | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | 0.03 | 0.03 | 0.021 |
| MgO | 0.10 | 0.41 | 0.20 | 0.15 | 0.41 | 0.53 | 0.44 | 0.42 | 0.37 |
| CaO | 0.44 | 0.82 | 0.36 | 0.48 | 0.29 | 0.37 | 0.84 | 0.84 | 0.74 |
| $Na_2O$ | 3.94 | 3.27 | 2.91 | 3.11 | 1.84 | 2.90 | 3.20 | 2.90 | 2.64 |
| $K_2O$ | 4.72 | 5.14 | 4.89 | 4.91 | 4.40 | 5.00 | 4.96 | 4.96 | 5.25 |
| $H_2O^+$ | 0.72 | 0.89 | 1.05 | 1.06 | 1.12 | 1.40 | 1.02 | 0.98 | 0.44 |
| $H_2O^-$ | 0.07 | 0.18 | 1.17 | 0.10 | 0.15 | 0.15 | 0.15 | 0.14 | - |
| $P_2O_5$ | n.d. | n.d. | n.d. | n.d. | 0.16 | 0.17 | 0.14 | 0.17 | 0.185 |
| $CO_2$ | 0.10 | - | 0.03 | - | 0.29 | 0.29 | 0.55 | 0.41 | n.d. |
| S | 0.01 | - | tr. | - | 0.05 | 0.03 | 0.03 | 0.04 | n.d. |
| Total | 99.93 | 99.88 | 99.96 | 99.85 | 100.31 | 100.59 | 100.65 | 100.62 | 98.92 |
| ΣFe /FeO/ | 9.73 | 1.29 | 0.54 | 0.68 | 1.16 | 1.60 | 1.58 | 1.85 | 1.40 |
| Mol % An in plagiocl. | 4.35 | 11.09 | 5.42 | 7.90 | 3.09 | 3.49 | 10.2 | 12.8 | 10.8 |
| Normative recalculated | | | | | | | | | |
| Q | 36.07 | 35.61 | 42.96 | 41.25 | 54.94 | 40.32 | 37.00 | 38.90 | 40.14 |
| Ab | 35.39 | 30.73 | 26.29 | 27.93 | 16.86 | 27.17 | 30.38 | 27.93 | 25.19 |
| Or | 29.54 | 33.66 | 30.75 | 30.82 | 28.20 | 32.51 | 32.61 | 33.17 | 34.66 |
| Q | 52.88 | 48.30 | 57.04 | 55.28 | 65.62 | 54.58 | 50.50 | 50.90 | 51.43 |
| Or | 44.55 | 45.66 | 40.83 | 41.31 | 33.69 | 44.01 | 44.51 | 43.41 | 44.41 |
| An | 2.57 | 6.04 | 2.12 | 3.41 | 0.68 | 1.40 | 4.99 | 6.68 | 4.16 |
| Q | 48.60 | 50.30 | 60.64 | 57.51 | 75.91 | 58.83 | 52.09 | 54.55 | 58.53 |
| Ab | 49.04 | 43.41 | 37.10 | 38.94 | 23.30 | 39.65 | 42.76 | 39.24 | 36.73 |
| An | 2.35 | 6.29 | 2.26 | 3.55 | 0.79 | 1.51 | 5.15 | 6.10 | 4.73 |
| Trace elements | | | | | | | | | |
| Rb ppm | 554 | 251 | 366 | 473 | 287 | 225 | 240 | 330 | 272 |
| Sr ppm | 4.3 | 73.9 | 20.5 | 22.3 | 33.6 | 43.5 | 56.2 | 47.00 | 43.5 |
| Rb/Sr | 128.83 | 3.40 | 17.80 | 21.21 | 8.54 | 5.17 | 4.27 | 7.02 | 6.25 |
| K/Rb | 70 | 170 | 111 | 86 | 127 | 184 | 171 | 124 | 160 |

The sample numbers correspond to the numbers of sampling localities in Text-fig. 1

* Sample derived from Czechoslovakia, the locality is not marked in Text-fig. 1

Table 2

Chemical analyses of typical Izera gneisses (weight %)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of the sample | 1 | 2a | 2b | 3 | 4 | 5 | 6 | 6b* | 7 | 12a |
| $SiO_2$ | 70.42 | 72.48 | 70.66 | 74.22 | 69.20 | 77.04 | 70.91 | 76.67 | 74.85 | 72.91 |
| $TiO_2$ | 0.47 | 0.36 | 0.39 | 0.18 | 0.58 | 0.09 | 0.47 | 0.03 | 0.26 | 0.34 |
| $Al_2O_3$ | 14.55 | 14.40 | 15.07 | 12.92 | 16.37 | 12.27 | 14.02 | 13.08 | 12.68 | 13.47 |
| $Fe_2O_3$ | 0.04 | 0.16 | 0.49 | 0.12 | 0.32 | 0.31 | 0.28 | 0.04 | 0.02 | 0.78 |
| FeO | 2.17 | 1.41 | 1.26 | 1.03 | 2.53 | 0.68 | 1.84 | 0.15 | 1.49 | 1.62 |
| MnO | 0.04 | 0.03 | 0.03 | 0.04 | 0.04 | 0.02 | 0.04 | 0.01 | 0.03 | 0.05 |
| MgO | 0.79 | 0.58 | 0.62 | 0.35 | 0.87 | 0.22 | 0.70 | 0.06 | 0.45 | 0.57 |
| CaO | 1.15 | 1.23 | 0.97 | 1.38 | 1.38 | 0.24 | 1.48 | 0.25 | 1.17 | 1.15 |
| $Na_2O$ | 3.20 | 3.35 | 3.28 | 3.73 | 3.25 | 2.78 | 3.73 | 5.12 | 3.44 | 3.51 |
| $K_2O$ | 4.97 | 4.73 | 5.76 | 5.21 | 4.83 | 5.36 | 4.99 | 5.33 | 4.78 | 4.32 |
| $H_2O^+$ | 1.08 | 0.97 | 1.28 | 0.76 | 1.28 | 0.86 | 1.40 | 0.23 | 0.67 | 1.02 |
| $H_2O^-$ | 0.20 | 0.15 | 0.19 | 0.14 | 0.12 | 0.12 | 0.16 | 0.06 | 0.12 | 0.10 |
| $P_2O_5$ | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| $CO_2$ | 0.10 | 0.05 | 0.07 | 0.07 | - | - | 0.37 | 0.07 | - | 0.11 |
| S | 0.03 | tr. | tr. | 0.01 | - | tr. | tr. | tr. | 0.01 | - |
| Total | 99.20 | 99.90 | 100.06 | 100.16 | 99.77 | 100.01 | 100.39 | 100.10 | 99.96 | 99.96 |
| ΣFe /FeO/ | 2.21 | 1.55 | 1.69 | 1.13 | 2.82 | 0.96 | 2.09 | 0.19 | 1.50 | 2.32 |
| Mol. % An in plagiocl. | 15.1 | 16.1 | 13.2 | 8.2 | 19.0 | 4.7 | 13.1 | - | 14.4 | 14.0 |
| Normative recalculated | | | | | | | | | | |
| Q | 33.02 | 35.34 | 29.42 | 32.12 | 31.71 | 41.72 | 29.74 | 28.90 | 36.24 | 36.85 |
| Ab | 32.27 | 32.52 | 31.52 | 34.46 | 33.53 | 24.90 | 36.39 | 38.73 | 32.31 | 33.73 |
| Or | 34.71 | 32.14 | 39.06 | 33.42 | 34.76 | 33.38 | 33.87 | 32.37 | 31.45 | 29.42 |
| Q | 44.74 | 47.72 | 40.00 | 48.68 | 42.39 | 54.61 | 42.83 | 47.17 | 49.35 | 51.14 |
| Or | 47.02 | 43.39 | 53.11 | 46.56 | 46.47 | 43.70 | 48.78 | 52.83 | 42.82 | 40.82 |
| An | 8.24 | 8.89 | 6.89 | 4.76 | 11.14 | 1.69 | 8.39 | - | 7.83 | 8.04 |
| Q | 46.26 | 47.48 | 44.56 | 45.99 | 43.10 | 61.42 | 41.32 | 42.73 | 48.77 | 48.25 |
| Ab | 45.21 | 43.68 | 47.76 | 49.33 | 45.57 | 36.67 | 50.58 | 57.27 | 43.48 | 44.16 |
| An | 8.53 | 8.84 | 7.68 | 4.68 | 11.33 | 1.91 | 8.10 | - | 7.75 | 7.59 |
| Trace elements | | | | | | | | | | |
| Rb ppm | 188 | 171 | 175 | 225 | 170 | 267 | 175 | 139 | 270 | 190 |
| Sr ppm | 146 | 110 | 134 | 50 | 110 | 17.5 | 82 | 17.6 | 59.3 | 70 |
| Rb/Sr | 1.29 | 1.55 | 1.31 | 4.50 | 1.54 | 15.26 | 2.13 | 7.90 | 4.55 | 2.71 |
| K/Rb | 219 | 229 | 272 | 192 | 235 | 166 | 234 | 318 | 147 | 188 |

The sample numbers correspond to the numbers of sampling localities in Text-fig. 1

* Aplite

only points of slight dissimilarity for the Rumburk granites are that some of them are a little more Rb-rich than the gneisses with the same content of $SiO_2$ and that the lack of negative correlation is not so evident in $K_2O$ vs $SiO_2$ diagram as for the gneisses. These features do not appear opposed to the general conclusion that arises from considering all the diagrams the composition of the Rumburk granite covers

Table 2 (cnt'd)

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|
| No of the sample | 12b | 12c | 13 | 14 | 22 | 23 | 24b | 25a | 25b | 25c |
| $SiO_2$ | 75.08 | 74.20 | 76.13 | 77.46 | 73.31 | 74.83 | 76.36 | 76.12 | 76.87 | 75.58 |
| $TiO_2$ | 0.19 | 0.19 | 0.18 | 0.07 | 0.33 | 0.24 | 0.16 | 0.12 | 0.11 | 0.06 |
| $Al_2O_3$ | 13.08 | 13.54 | 12.70 | 12.39 | 14.07 | 13.66 | 12.83 | 12.73 | 12.54 | 13.24 |
| $Fe_2O_3$ | 0.26 | 0.48 | 0.22 | 0.35 | 0.32 | 0.01 | 0.38 | 0.13 | 1.00 | 1.05 |
| FeO | 0.97 | 1.11 | 0.68 | 0.36 | 0.96 | 0.83 | 0.42 | 0.88 | 0.23 | 0.36 |
| MnO | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 |
| MgO | 0.50 | 0.35 | 0.20 | 0.19 | 0.70 | 0.51 | 0.25 | 0.42 | 0.31 | 0.33 |
| CaO | 1.27 | 0.93 | 0.43 | 0.27 | 0.60 | 0.24 | 0.47 | 0.89 | 0.49 | 0.47 |
| $Na_2O$ | 2.83 | 3.09 | 3.08 | 2.75 | 3.26 | 2.66 | 3.32 | 4.03 | 3.16 | 2.64 |
| $K_2O$ | 4.74 | 4.67 | 5.29 | 5.18 | 5.11 | 5.67 | 4.70 | 3.35 | 3.81 | 4.52 |
| $H_2O^+$ | 0.77 | 0.78 | 0.81 | 0.94 | 1.34 | 1.25 | 1.03 | 0.99 | 0.87 | 0.85 |
| $H_2O^-$ | 0.07 | 0.11 | 0.12 | 0.09 | 0.13 | 0.12 | 0.15 | 0.07 | 0.00 | 0.03 |
| $P_2O_5$ | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. | 0.19 | 0.22 |
| $CO_2$ | - | 0.07 | 0.07 | - | - | - | 0.04 | 0.28 | 0.44 | 0.66 |
| S | tr. | - | - | - | - | tr. | tr. | tr. | 0.06 | 0.03 |
| Total | 99.79 | 99.76 | 99.93 | 100.06 | 100.04 | 100.04 | 100.12 | 100.06 | 100.10 | 100.07 |
| ΣFe /FeO/ | 1.20 | 1.54 | 0.88 | 0.67 | 1.25 | 0.83 | 0.76 | 1.00 | 1.07 | 1.30 |
| Mol % An in plagiocl. | 19.71 | 14.60 | 6.49 | 5.01 | 8.02 | 4.86 | 6.64 | 6.58 | 4.79 | 5.30 |
| Normative recalculated | | | | | | | | | | |
| Q | 41.28 | 38.76 | 39.16 | 36.36 | 35.93 | 38.73 | 39.85 | 41.78 | 46.71 | 45.87 |
| Ab | 27.02 | 29.14 | 27.70 | 27.59 | 30.63 | 24.60 | 30.17 | 36.92 | 29.40 | 24.66 |
| Or | 31.69 | 32.10 | 33.14 | 36.05 | 33.43 | 36.67 | 29.98 | 21.30 | 23.89 | 29.47 |
| Q | 51.59 | 51.28 | 52.82 | 49.16 | 49.80 | 50.48 | 55.27 | 63.45 | 64.73 | 59.73 |
| Or | 39.60 | 42.47 | 44.69 | 48.74 | 46.34 | 47.79 | 41.57 | 32.35 | 33.09 | 38.37 |
| An | 8.81 | 6.25 | 2.49 | 2.10 | 3.85 | 1.73 | 3.16 | 4.20 | 2.18 | 1.90 |
| Q | 54.79 | 53.37 | 57.00 | 55.51 | 51.82 | 59.91 | 55.12 | 51.28 | 60.13 | 63.71 |
| Ab | 35.86 | 40.12 | 40.32 | 42.12 | 44.17 | 38.04 | 41.73 | 45.32 | 37.84 | 34.25 |
| An | 9.35 | 6.51 | 2.68 | 2.37 | 4.01 | 2.05 | 3.15 | 3.40 | 2.03 | 2.03 |
| Trace elements | | | | | | | | | | |
| Rb ppm | 160 | 281 | 370 | 270 | 205 | 190 | 250 | 222 | 207 | 317 |
| Sr ppm | 52 | 52.3 | 21.8 | 25.9 | 35 | 50. | 30 | 48.8 | 30.7 | 25.5 |
| Rb/Sr | 3.08 | 5.37 | 16.97 | 10.42 | 5.86 | 3.80 | 8.33 | 4.55 | 6.74 | 12.43 |
| K/Rb | 245 | 144 | 118 | 159 | 207 | 247 | 156 | 126 | 150 | 119 |

one part of the composition range of the Izera gneisses. The two rock groups constitute therefore one common geochemical complex.

Finally, the question arises if the geochemical data are consistent with the hypothesis of only one co-genetic magmatic series. The Harker diagrams show common evolutive tendencies. This is valid both for the elements showing negative correlation with $SiO_2$, and for those of abundance independent of $SiO_2$. It can be observed in all the diagrams that the compositions of gneisses which deviate from those of the granites have a calc-alkaline tendency: relative abundance of plagioclase in the triangle Q-Ab-An (Text-fig. 3), increase of $Al_2O_3$, $\Sigma Fe$, MgO and CaO content while the $SiO_2$ content decreases (Text-fig. 4), simultaneous diminution of Rb and $SiO_2$ (Text-fig. 6). The distribution of points representing the granites shows this trend.

Table 3

Chemical analyses of leucogneisses and leucogranites (weight %)

| No. of the sample | 1<br>8 | 2<br>9a | 3<br>9b | 4<br>10 | 5<br>11 | 6<br>24a |
|---|---|---|---|---|---|---|
| $SiO_2$ | 76.96 | 77.39 | 77.49 | 76.33 | 76.72 | 76.83 |
| $TiO_2$ | 0.07 | 0.08 | 0.10 | 0.11 | 0.12 | 0.11 |
| $Al_2O_3$ | 12.42 | 12.08 | 12.11 | 12.22 | 12.26 | 12.28 |
| $Fe_2O_3$ | 0.21 | 0.22 | 0.15 | 0.21 | 0.32 | 0.01 |
| FeO | tr. | 0.19 | - | 0.39 | 0.06 | 0.71 |
| MnO | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.03 |
| MgO | 0.12 | 0.16 | 0.12 | 0.21 | 0.13 | 0.27 |
| CaO | 0.62 | 0.42 | 0.53 | 0.86 | 0.69 | 0.74 |
| $Na_2O$ | 3.61 | 2.94 | 3.84 | 3.53 | 3.59 | 3.62 |
| $K_2O$ | 5.23 | 5.68 | 5.15 | 5.32 | 5.26 | 4.67 |
| $H_2O^+$ | 0.55 | 0.56 | 0.35 | 0.64 | 0.64 | 0.62 |
| $H_2O^-$ | 0.04 | 0.08 | 0.05 | 0.12 | 0.08 | 0.12 |
| $P_2O_5$ | n.d. | n.d. | n.d. | n.d. | n.d. | n.d. |
| $CO_2$ | - | 0.09 | 0.04 | - | 0.09 | - |
| S | - | - | - | tr. | - | - |
| Total | 99.84 | 99.90 | 99.94 | 99.96 | 99.97 | 100.01 |
| $\Sigma Fe$ /FeO/ | 0.21 | 0.39 | 0.15 | 0.58 | 0.35 | 0.71 |
| Mol. % An in plagiocl. | 7.04 | 5.57 | 2.23 | 6.14 | 5.86 | 9.8 |
| Normative recalculated | | | | | | |
| Q | 36.21 | 38.98 | 36.63 | 35.70 | 35.74 | 37.81 |
| Ab | 31.73 | 25.84 | 33.25 | 31.31 | 31.80 | 32.68 |
| Or | 32.06 | 35.18 | 31.12 | 32.99 | 32.46 | 29.51 |
| Q | 51.14 | 51.44 | 52.74 | 50.37 | 50.84 | 53.25 |
| Or | 45.27 | 46.42 | 46.07 | 46.55 | 46.18 | 41.56 |
| An | 3.59 | 2.14 | 1.19 | 3.08 | 2.98 | 5.19 |
| Q | 51.37 | 58.67 | 51.13 | 51.59 | 51.32 | 50.97 |
| Ab | 45.02 | 38.89 | 47.72 | 45.25 | 45.66 | 44.06 |
| An | 3.61 | 2.44 | 1.15 | 3.16 | 3.02 | 4.97 |
| Trace elements | | | | | | |
| Rb ppm | 138 | 298 | 301 | 305 | 376 | 281 |
| Sr ppm | 50 | 105 | 55.6 | 37.8 | 34.2 | 21.6 |
| Rb/Sr | 2.76 | 2.84 | 5.41 | 8.07 | 10.99 | 13.01 |
| K/Rb | 314 | 158 | 142 | 145 | 116 | 138 |

The sample numbers correspond to the numbers of sampling localities in Text-fig. 1

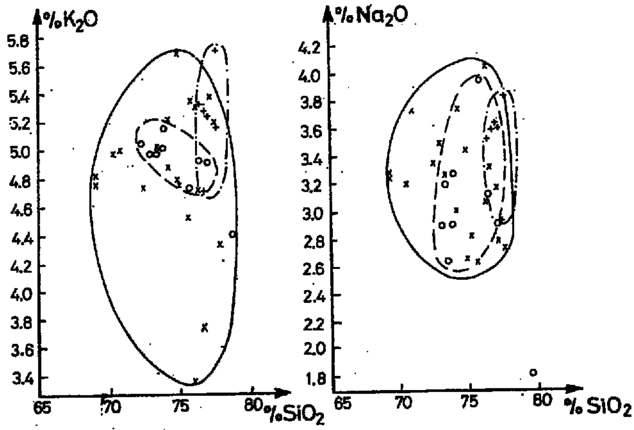


Fig. 5. Harker's diagrams $K_2O/SiO_2$ and $Na_2O/SiO_2$ for Izera gneisses (X), Rumburk granites (O) and leucogneisses (+). The deviated point represents cataclased granite No. *20*

In the diagram K/Rb as a function of K-content, the representative points define trends different from those usually observed in magmatic sequences (Text-fig. 7). These tendencies are: (*a*) main trend where K/Rb = *const.* while K varies, (*b*) diminution of K/Rb while K increases (Shaw 1968). In our case, on the contrary, the K/Rb ratios vary independently of the variation of K. This latter characteristic is typical of anorogenic peralkali and alkali granites (Vidal & *al.* 1977). As this

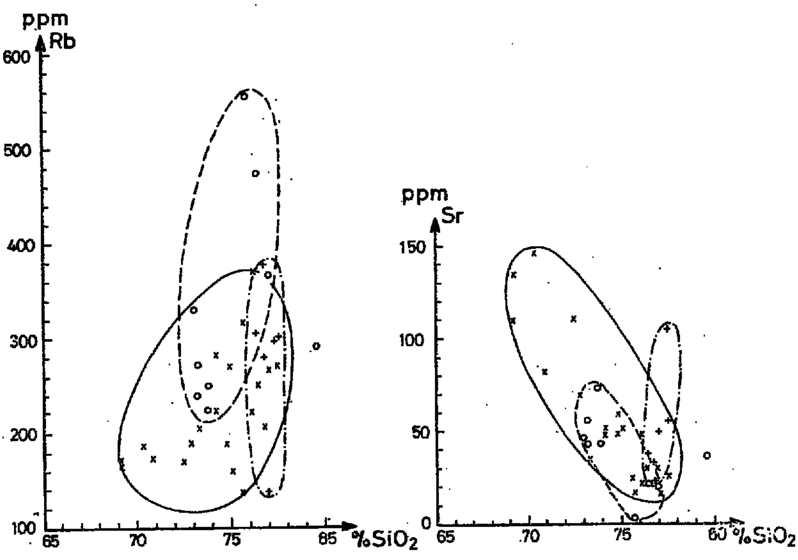


Fig. 6
$Rb/SiO_2$ and $Sr/SiO_2$ diagrams for Izera gneisses (X), Rumburk granites (O) and leucogneisses (+)

property concerns both the Rumburk granites and the Izera gneisses, it is difficult to assume that the association of these two formations is fortuitous.

In consequence, the above data indicate well a common magmatic origin of both the Izera gneisses and the Rumburk granites.

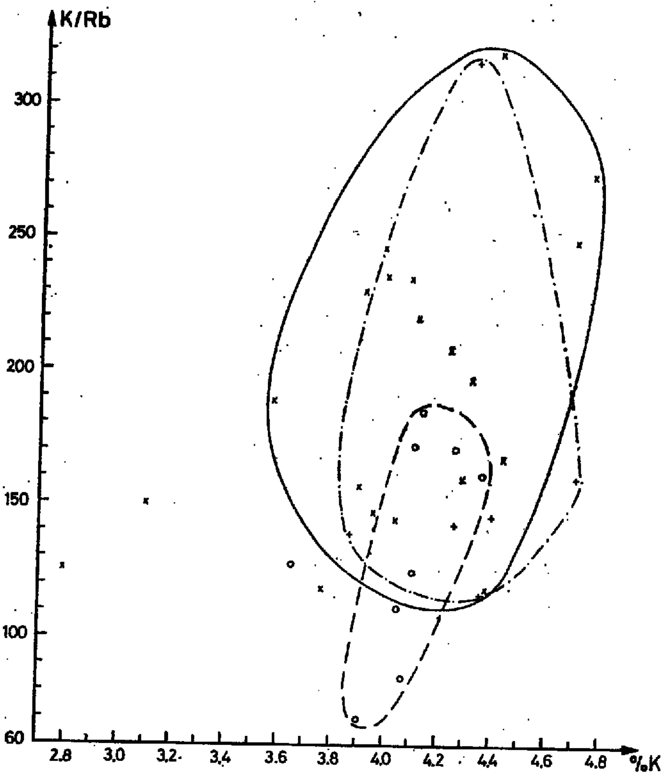


Fig. 7
K/Rb vs K diagram for Izera gneisses (X), Rumburk granites (O) and leucogneisses (+)

## GEOCHRONOLOGY AND ISOTOPIC GEOCHEMISTRY

The rubidium-strontium method was used to furnish new information on the following questions: (*1*) age and origin of the Rumburk granite; (*2*) relationship between the Rumburk granites, the typical Izera gneisses and the leucogneisses; (*3*) the extent of the Hercynian thermal influence.

Twenty six samples were selected for isotopic analyses (Table 4). Rubidium-strontium analyses were performed on 100 mg aliquots of powdered samples. Strontium was extracted by standard cation exchange techniques. Rubidium and strontium contents were determined by isotopic dilution. The samples were loaded onto oxidized tantalum filaments and analysed on a TSN 206 mass spectrometer (radius 30 cm, 60° sector, operating at 10 kV). The data processing was performed by an on-line Hewlett-Packard 9825 calculator. The measured value for the standard NBS 987 was 0.71020 at the time this work was in progress. The error ($2\sigma/m$) for an individual run is typically of the order 0.05%. Ages were calculated with the York method (1966) using $\lambda^{87}Rb = 1.42 \cdot 10^{-11}\ y^{-1}$ giving 2% error on the $^{87}Rb/^{86}Sr$ ratio.

## RUMBURK GRANITE

Eight samples were analysed, one of them being an aplite (sample No. *16*). Five samples originated from Poland, two from GDR (Nos *20* and *21*) and one from Czechoslovakia (No. *32*).

Table 4

Results of rubidium-strontium analyses

Rumburk granites

| | Nos of table 1 | Rb | Sr | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|---|---|
| 3283 | 16 | 554 | 4.30 | 370 | 3.372 |
| 3284 | 17 | 251 | 73.9 | 9.85 | 0.7784 |
| 3285 | 18 | 365 | 20.5 | 51.6 | 1.0692 |
| 3286 | 19 | 473 | 22.3 | 61.2 | 1.1486 |
| 4249 | 32 | 272 | 49.5 | 15.19 | 0.8154 |
| 4252 | 20 | 287 | 34.3 | 24.53 | 0.8539 |
| 4253 | 21 | 225 | 44.3 | 14.48 | 0.8010 |
| 4254 | 15 | 240 | 57.3 | 12.19 | 0.7915 |

Izera gneisses

| | Nos of table 2 | Rb | Sr | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|---|---|
| 3287 | 1 | 188 | 146 | 3.73 | 0.7336 |
| B3287 | | 637 | 9.55 | 193.1 | |
| 3288 | 6 | 175 | 82.02 | 6.16 | 0.7493 |
| 3289 | 6b | 139 | 17.6 | 22.9 | 0.8184 |
| 3290 | 25a | 222 | 48.8 | 13.2 | 0.7892 |
| 3291 | 13 | 370 | 21.8 | 49.2 | 1.0406 |
| 3292 | 12c | 281 | 52.3 | 15.6 | 0.8103 |
| B3292 | | 1517 | 4.26 | 1031 | 5.3855 |
| 3362 | 2a | 171 | 110 | 4.46 | 0.7396 |
| 3363 | 2b | 175 | 134 | 3.78 | 0.7336 |
| 3364 | 7 | 270 | 59.3 | 13.16 | 0.7939 |
| 3365 | 14 | 270 | 25.9 | 30.13 | 0.8743 |
| 4247 | 25c | 317 | 25.5 | 36.1 | 0.9124 |
| 4248 | 25b | 207 | 31.4 | 19.11 | 0.8245 |
| 4278 | 5 | 267 | 17.8 | 43.38 | 0.9791 |
| M4278 | | 837 | 8.77 | 276 | |

Leucogneisses

| | Nos of table 3 | Rb | Sr | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|---|---|
| 3366 | 24a | 281 | 21.6 | 37.77 | 0.9586 |
| 3367 | 11 | 376 | 34.2 | 31.82 | 0.8960 |
| 3368 | 10 | 305 | 37.8 | 23.38 | 0.8554 |
| 3369 | 9b | 301 | 55.6 | 15.69 | 0.8052 |
| 3370 | 9a | 298 | 105 | 8.21 | 0.7559 |
| M3370 | | | 24.0 | | 1.2491 |

Karkonosze granite

| | | Rb | Sr | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ |
|---|---|---|---|---|---|
| B4642 | | 984 | 3.50 | 813 | 4.3842 |
| B4643 | | 1048 | 18.5 | 164 | 1.4292 |

B = biotite

M = muscovite

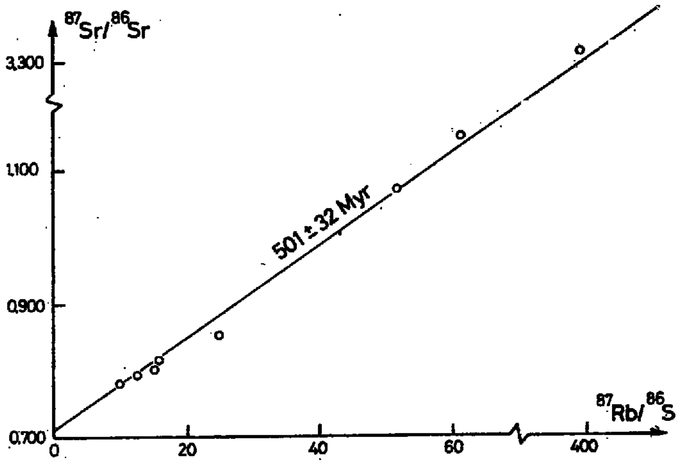


Fig. 8
$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for Rumburk granites

As demonstrated in the preceding section, the Rumburk granites are characterized by generally high Rb content, low Sr content and a large spread in their Rb/Sr ratios. The results are shown in the $^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram (Text-fig. 8). The samples do not define a straight line. The mean square weighted deviation (MSWD) equals 51 and confirms that we are dealing with an errorchron. The calculated age is 492±45 Myr and the initial $^{87}Sr/^{86}Sr$ ratio is 0.7048±0.0110.

IZERA GNEISSES

Twelve samples have been analysed, and they exhibit Rb/Sr characteristics similar to that of the Rumburk granite. A strongly scattered pattern is also observed in the $^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram (Text-fig. 9). The age is 427±24 Myr and the initial $^{87}Sr/^{86}Sr$ ratio is 0.7112±0.0027; the MSWD is 37.

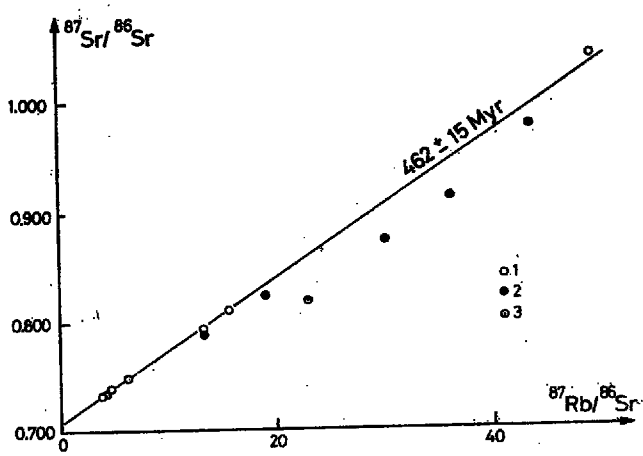


Fig. 9
$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for Izera gneisses
*1* — typical Izera gneisses, *2* — border facies, *3* — aplite

LEUKOGNEISSES

Five hololeucocratic rock samples have been analysed. The results are also scattered beyond the analytical errors (Text-fig. 10). The age is confirmed as 456±36 Myr and the initial $^{87}Sr/^{86}Sr$ ratio as 0.7024±0.0078 (MSWD = 20).

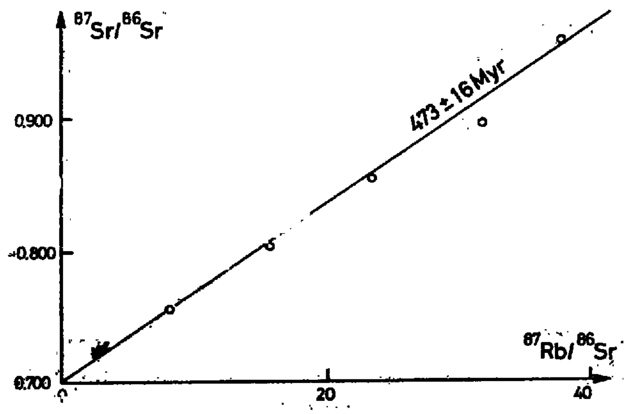


Fig. 10
$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for leucogneisses

APLITE

An aplitic dyke (sample No. *6b*) intruding the Izera gneiss complex gave a model age of 350 Myr (using an initial $^{87}Sr/^{86}Sr$ ratio of 0.705).

MICAS

One muscovite from a leucogranite sample, one muscovite and two biotites from three Izera gneisses indicate ages between 310 and 320 Myr.

ORIGIN OF THE SCATTER IN THE $^{87}Sr/^{86}Sr$ VS $^{87}Rb/^{86}Sr$ DIAGRAMS

Four possibilities can be taken into consideration when explaining the scattered results: (*1*) the existence of several episodes of magmatism throughout a period of some tens of millions of years; (*2*) lack of initial isotopic homogenization among the rocks having an identical age of around 460—470 Myr. Such lack of homogenization could explain the position of several points (like Nos *16* and *19* which have model ages around 505 Myr) because the Sr isotopic ratios may grow very fast in liquids having very high Rb/Sr ratios (Vidal & *al.* 1977). It cannot explain, however, the position of points having lower model ages (*e.g.* Nos. *11* and *14*) as they would have had initial $^{87}Sr/^{86}Sr$ ratios too low to be acceptable; (*3*) the opening of the system during a subsequent metamorphism. It is well known that granites having high Rb/Sr ratios can be rather easily rejuvenated during a metamorphism, due to a mica like behaviour, by losing part or all the radiogenic strontium previously formed (Bottino & *al.* 1970; Delhal & *al.* 1971; Zartman & Marvin 1971); (*4*) the weathering under superficial conditions able to remove a part of the radiogenic strontium from the whole rock. In this respect, the samples *20* of the Rumburk granite and *11* of the leucogneiss, which exhibit evidence of weathering, plot below the majority of samples. The samples of the Izera gneisses derived from the border of the massif have been considered as metaarkoses. All these samples (Nos *5, 14, 25a, 25b, 25c*) plot distinctly below the typical Izera gneisses. This fact reflects their arkosic nature.

## AGE RELATIONSHIPS

When the weathered samples are discarded (No. *20* for Rumburk granite, Nos *5, 14, 25a, 25b, 25c* for Izera gneisses and No. *11* for leucogneisses) the results are as follows: (*1*) Rumburk granite: the remaining data are still scattered (MSWD = 22), and the age is 501 ± 32 Myr with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7046 ± 0.0074; (*2*) Izera gneisses: the remaining samples define an isochron (MSWD = 4.8) with an age of 462 ± 15 Myr and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7090 ± 0.0013; (*3*) Leucogneisses: the four remaining samples define an isochron (MSWD = 2.7) with an age of 473 ± 16 Mvr and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7003 ± ± 0.0032.

Within the analytical uncertainties, there are no significant age differences among these three units. Numerous examples known from the literature show clearly that the Rb-Sr method applied to the whole-rock analysis of orthogneisses records (in the majority of cases) the emplacement age of the precursors of the gneisses, i.e. the emplacement age of the granites. In our case, the three units mentioned have been emplaced between 500 and 450 Myr ago, being therefore of Lower Paleozoic age (Upper Cambrian-Lower/Mid-Ordovician).

## INITIAL $^{87}Sr/^{86}Sr$ RATIOS

The initial isotopic ratio of the Rumburk granite could not unfortunately be precisely established and it is therefore difficult to say if the granites of Rumburk derive from the Earth's mantle or are of a crustal origin. For the Izera gneisses, the initial $^{87}Sr/^{86}Sr$ ratio is 0.709, and this probably means a crustal origin for the precursor granite. It cannot correspond to an internal large scale isotopic redistribution during a subsequent metamorphism for the reason given in the preceding section. For the leucogneisses, the calculated initial $^{87}Sr/^{86}Sr$ ratio is too low to be acceptable (0.700), but within the analytical uncertainties, a more acceptable value can be reached (0.703). This ratio corresponds to mantle type isotopic ratios. However, due to the small number of samples, the hypothesis of eventual mantle origin for the leucogneisses must be taken with some reservation.

## SUBSEQUENT THERMAL HISTORY

The two muscovites and the two biotites have revealed dates between 310 and 320 Myr. In order to interpret the meaning of these dates we analysed two biotites from the nearby Karkonosze granite (*see* Table 4); the obtained results are 311 and 318 Myr. It is therefore very likely that the dates of the micas from the Izera gneisses also date a thermal event due to the emplacement of the post-tectonic Karkonosze granite. The aplite sample (No. *6b*), which has been subject to the same metamorphic processes as the gneisses, reveals a maximum model age of 350 Myr (using an initial $^{87}Sr/^{86}Sr$ ratio 0.705). Assuming a close system behaviour during the metamorphism for this aplite, the age of this metamorphism should be assigned as between 350 and 320 Myr.

## CONCLUSIONS

The Izera gneisses are closely related by their petrographic features to the plutonic rocks which border them in the west and into which the gneisses pass progressively. This similarity gave rise in the past to some controversy as to their relationships. The age of these formations remained in question.

We have demonstrated that the Rumburk granites are not distinguishable from the Izera gneisses in their chemical compositions. Their normative projection points are concentrated around the eutectic compositions in the system Quartz — Feldspars — $H_2O$.

In the present paper, some geological arguments have been set forth to demonstrate the intrusive nature of rocks related to the gneisses and therefore the orthoderived nature of these gneisses. As appears from the diagrams, the chemical composition of the gneisses also indicates their magmatic origin. The alignment of the gneisses on the isochrons could be a supplementary argument to support the magmatic origin of all these rocks.

The age of the intrusions under discussion is between 500 and 450 Myr. The discrepancy may be due to the inexactitude of the age determination of the Rumburk granite. For the gneisses, the related intrusions are dated more precisely between 480 and 450 Myr. (Lower/Mid-Ordovician) The penecontemporaneous leucogneisses within the orthogneiss complex appear to have a distinct origin, more infracrustal, and possibly mantle derived.

These new data agree perfectly with recent paleontological contributions to the dating of the Kaczawa Mts formations which were transformed by tectonometamorphism after Famennian times. Relics of hypovolcanic facies attest to the very high-level nature of the intrusion, the elevated temperature of which is evidenced by the feldspars. A rapid denudation was succeded by a transgression which was diachronous in nature; the earliest being put at the end of the Ordovician. The regional thermal event which accompanied tectogenesis is evidenced in all the plutonites but the intensity of tectonic fabric is very unequal. This event is post-Famennian and older than 310—320 Myr the younger age bracket corresponding to the post-tectonic emplacement of the Karkonosze granite.

The present study has revealed evidence for an anorogenic alkaline plutonism during the Ordovician period in the Western Sudetes. Such evidence, common in western Europe, is interpreted as reflecting a tendency to continental riftogenesis in this period (Vidal 1976). Our results now extend those conclusions to the central part of Europe.

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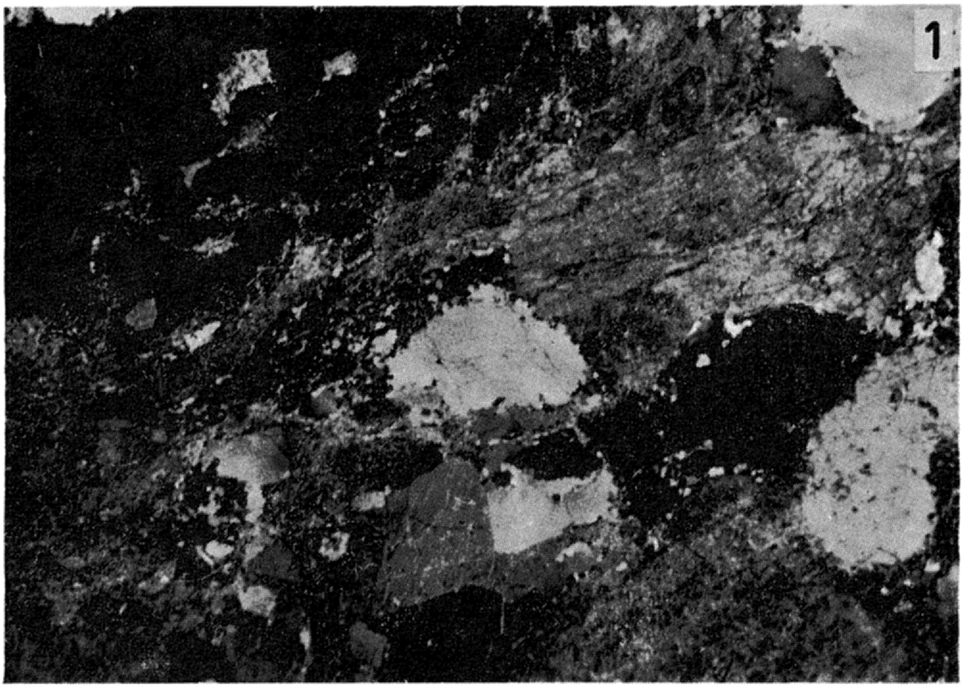
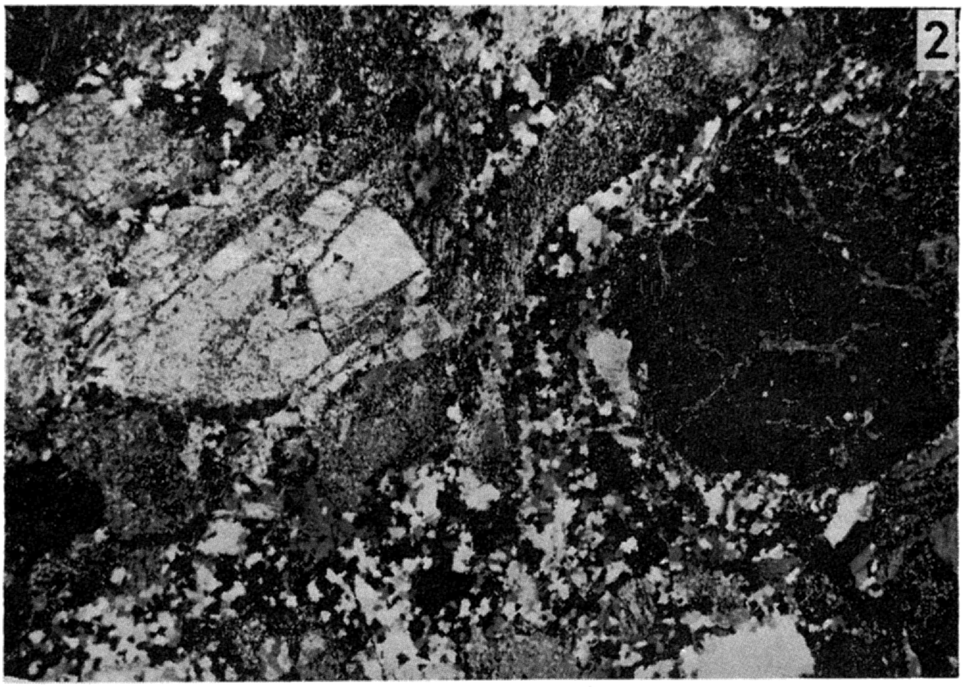


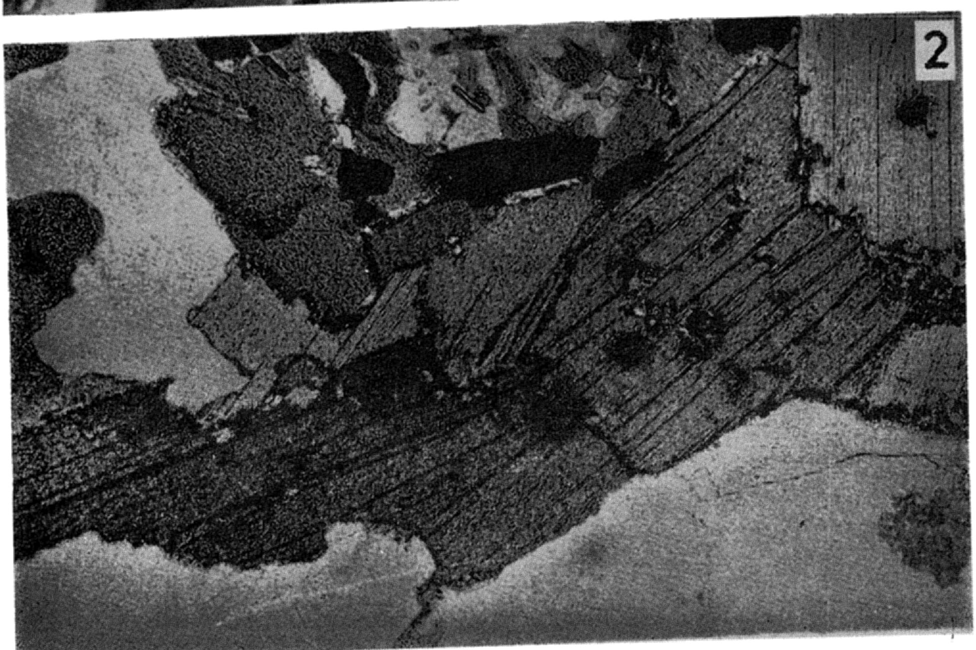




**1** — Izera gneiss from Siedlęcin (point *2* in Text-fig. 1); the cataclasis was here sufficiently advanced for developing a foliation; recrystallization similar to that of augengneisses; crossed nicols, ×6.5

**2** — Augengneiss from Wrzeszczyn (point *3* in Text-fig. 1); phenoclasts of alkali feldspar surrounded by finely granular feldspar and quartz fragments; recrystallization, weak for the feldspar, develops pavement quartz; crossed nicols, ×6.5

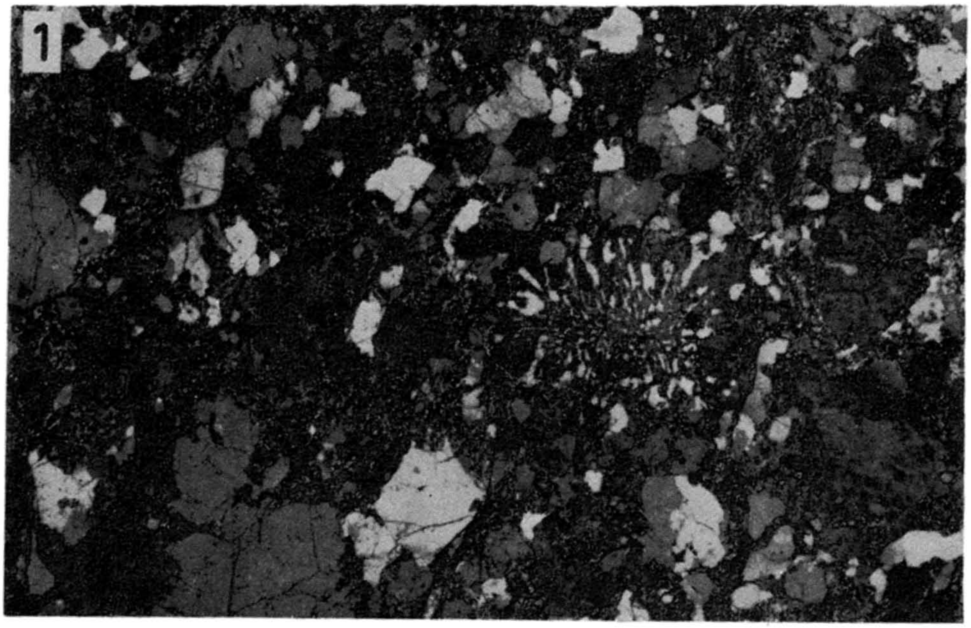
1 — Detail of alkali feldspar phenocryst of Izera gneiss from Siedlęcin; visible are microcline cross-hatching, and veins of perthitic albite; crossed nicols, ×60

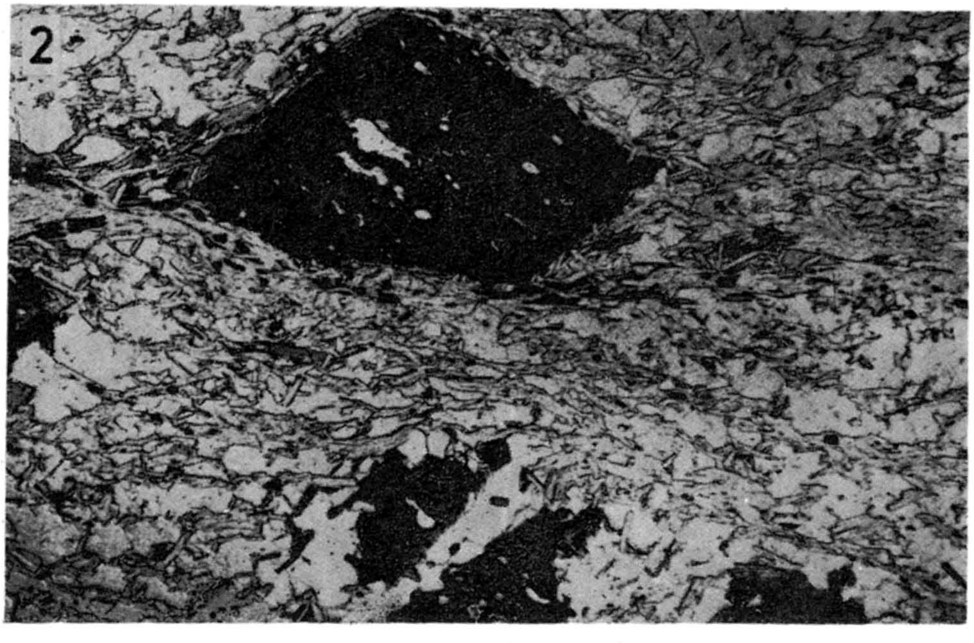
2 — Detail of alkali feldspar of the Rumburk granite from Wigancice; crossed nicols, ×60


1 — Rumburk granite from Wigancice (point *15* in Text-fig. 1); the rock has suffered a slight compression but is not foliated; crossed nicols, ×6.5

2 — The same granite: biotite plates concentrated into isolated cluster developed during secondary recrystallization of large primary phenocrysts; parallel nicols, ×65



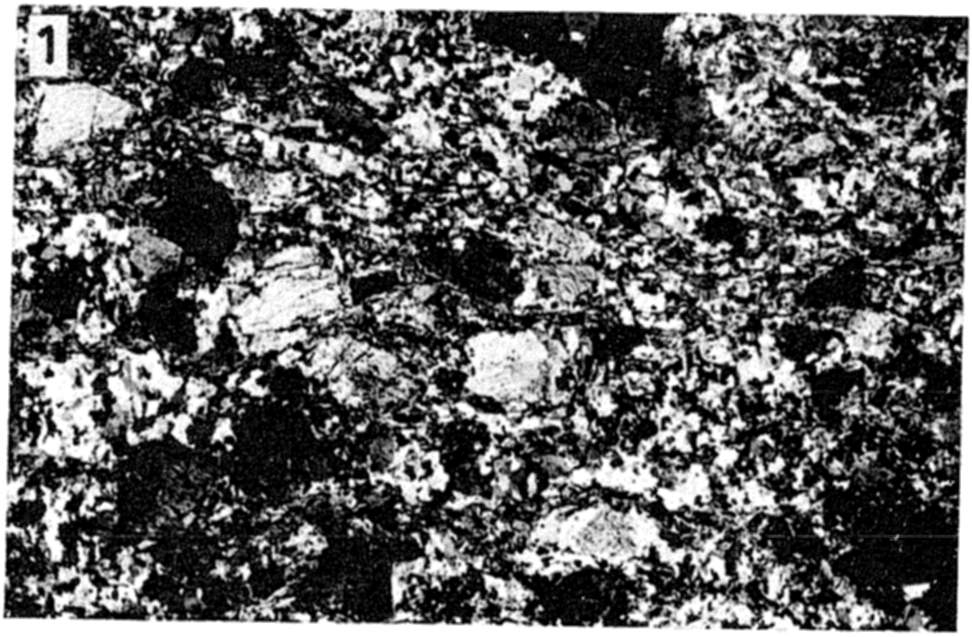


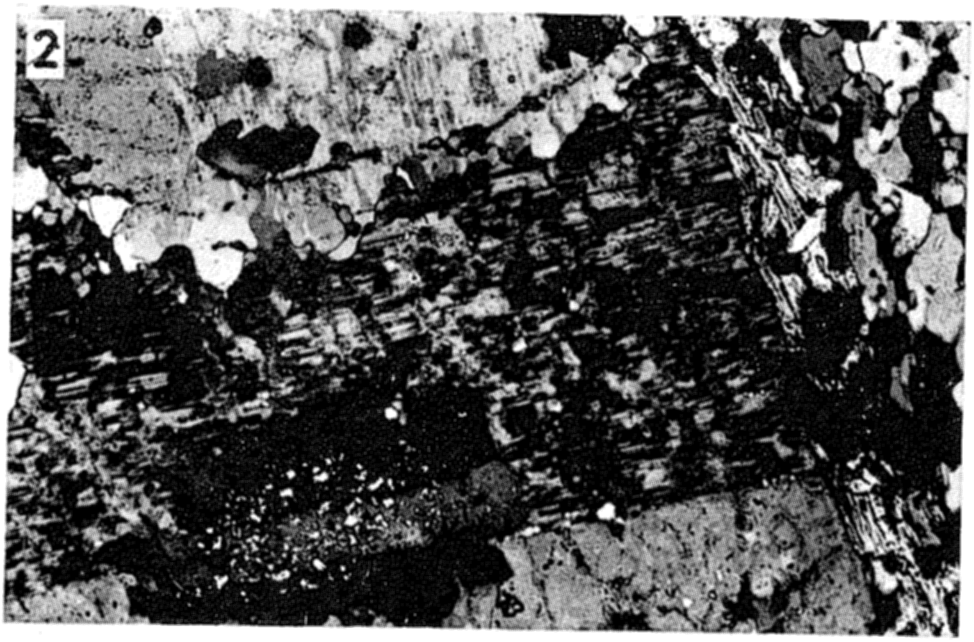
1 — Alkali feldspar granite from Platerówka (point *23* in Text-fig. 1) with micropegmatitic quartz; static recrystallization after a slight cataclasis; crossed nicols, ×7.5

2 — "Leptinite" from Kotlina (point *11* in Text-fig. 1); phenoblast of biotite preserving by its inclusions the surface $S_0$; deformation of the blast by foliation is visible; parallel nicols, ×50

1 — Poeciloblastic garnet in a layer enriched in micas within the "leptinites" of Kotlina; crossed nicols, ×120

2 — Prasinite of Siedlęcin; metamorphic development of albite blasts in chloritic groundmass; crossed nicols, ×45





1 — Marginal facies of Izera gneisses from Pilchowice; metaarkose recrystallized after having suffered a slight compression; the biggest crystals are detrital fragments of alkali feldspar; crossed nicols, ×6.5

2 — Detail of a detrital fragment of alkali feldspar containing plagioclase from the same gneiss; metamorphic recrystallization develops a narrow fringe of burgeonning expansion on the border of spotty albite; crossed nicols, ×65

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## POCHODZENIE I WIEK GNEJSÓW IZERSKICH I GRANITÓW RUMBURSKICH

### (Streszczenie)

W pracy przedstawiono związki petrologiczne, geochemiczne i geochronologiczne gnejsów izerskich z granitami rumburskimi. Wykazano, że typowe gnejsy izerskie nie różnią się swym składem od granitów rumburskich, przy czym skład ten wskazuje na ich magmową genezę (*patrz* fig. 1—10, tab. 1—4 oraz pl. 1—6). Pierwotnie intruzyjny charakter dzisiejszych gnejsów izerskich potwierdziły nowe obserwacje geologiczne. Dodatkowym argumentem przemawiającym za magmowym pochodzeniem tych skał jest ich uszeregowanie na izochronach.

Gnejsy izerskie tworzą wraz z granitami rumburskimi wspólny kompleks skalny powstały 500—450 milionów lat temu. Intruzja granitów (dzisiejszych gnejsów) izerskich datowana jest na 480—450 milionów lat, zaś ich deformacja jest pofameńska, lecz starsza od 310—320 milionów lat.