Sbor. geol. věd	Užitá geofyz., 24	Pages 9–49	6 figs.	3 tabs.	– pl.	Praha 1990 ISSN 0036-5319

Airborne geophysical survey in southwest Bohemia (Šumava Mts. piedmont) and its interpretation

Letecké geofyzikální měření v jihozápadních Čechách (Pošumaví) a jeho interpretace

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Received September 22, 1988

1 : 50 000
21–22, 24, 42
22–11–14, 23, 31–34, 41, 43

Airborne methods
Interpretation
Petrophysics
Magnetic properties
Petrology

Dědáček, K. – Mašín, J. – Šfovíčková, N. – Vejnar, Z. – Veselý, V. (1990): Airborne geophysical survey in southwest Bohemia (Šumava Mts. piedmont) and its interpretation. – Sbor. geol. Věd, užitá Geofyz., 24, *9–49*. Praha.

Abstract: In southwest Bohemia an area of approx. 3 400 km² was covered by new airborne magnetometric and gamma spectrometric survey on the scale of 1 : 25 000. In the Barrandian Proterozoic of the surveyed area an expressive zone of magnetic anomalies has been observed over the belts of the products of paleobasalt volcanism, corresponding with the zones of decreased concentration of K, U and Th. Petrological and petrophysical studies proved pyrrhotite as the main carrier of magnetization in the paleobasalts. The surveyed parts of the Central Bohemian Pluton do not exhibit magnetic anomalies. The north-western boundaries of the partial apophyses of the Pluton are distinctly marked in the field of K, U and Th concentrations. In the islets of the Pluton crystalline mantle, the striking magnetic anomalies are associated with products of mafic and also felsic volcanism, containing magnetite. The radiometric anomalies indicate great variability of the rocks of the islet-zone. The Moldanubian part of the study area is characterized by the regional magnetic zones, trending NE–SW. The sources of these zones are metamorphosed volcanics of contrast chemism, containing magnetite. The anomalies of radioactivity, trending E–W, can be traced several tens of kilometers. They are associated with the system of dykes of porphyries and porphyrites.

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Introduction

In 1982 a new stage of airborne geophysical measurements (magnetometric and gamma spectrometric) and geological interpretation of selected areas in the Bohemian Massif has stard. teIn each selected area (approx. of 3 500 km^2) the project is going on in a three-year cycle. The first year is devoted to airborne measurements. The results, i.e. contour maps of ΔT anomalies, total gamma activity and K, U and Th concentrations, are used for planning of the ground verification and selecting anomalies for a detailed survey. These works are carried out during the second year and serve as a basis for geophysical interpretation. The maps of primary data processing are verified and the set of airborne maps is enhanced by the derived magnetic maps (continuation upward to 200 and 750 m above the flight elevation, vertical gradient) and derived gamma spectrometric maps (ratios of Th/U, Th/K concentrations). During the third year, the verified and derived maps are used for complex geophysical and geological interpretation.

The area in southwest Bohemia (Šumava Mts. piedmont) where the airborne survey and the subsequent geological interpretation were accomplished in 1985, includes the southern part of the Central Bohemian Pluton and the adjoining part of the Moldanubicum and Barrandian (approx. 3 400 km^2).

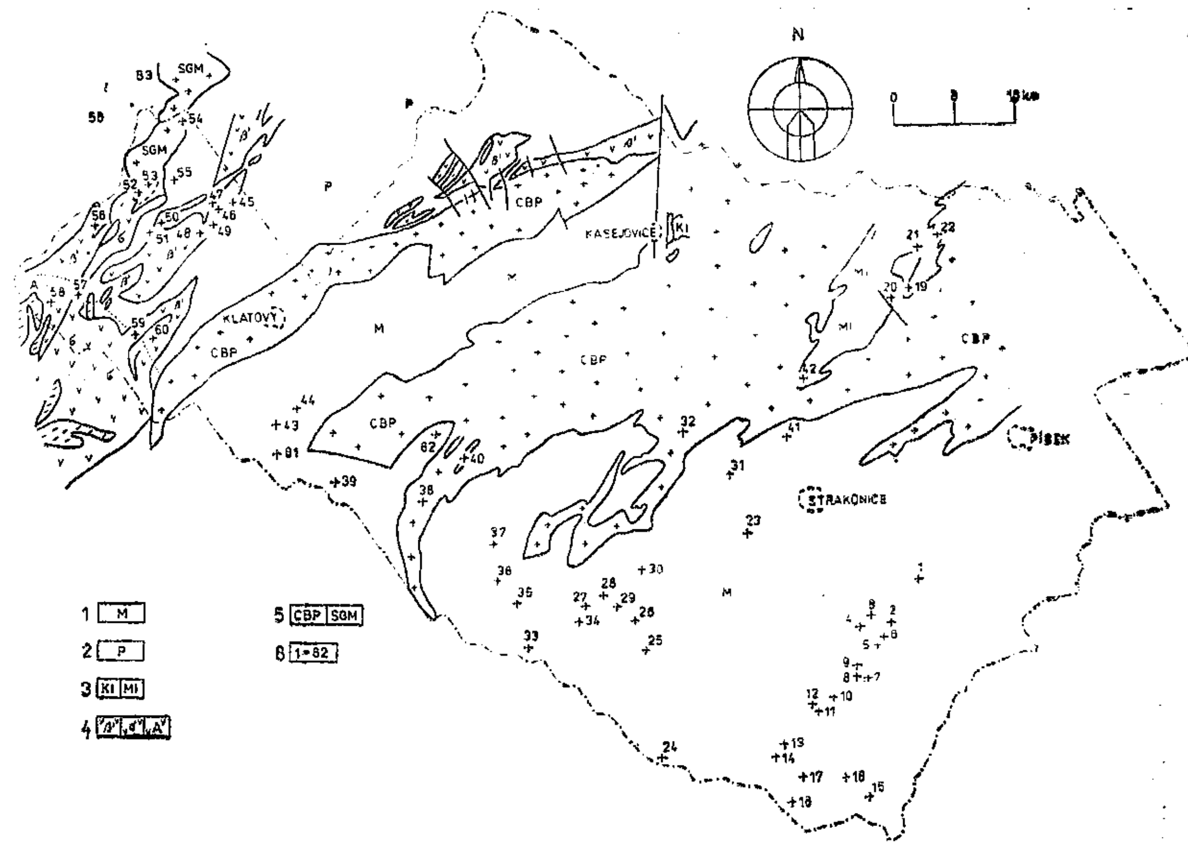
Geological review

The study area includes the following regional-geological units (from W to E): 1. The Domažlice crystalline complex, 2. The Barrandian basin, 3. The Central Bohemian Pluton, 4. The Šumava section of the Moldanubicum (cf. Fig. 1).

The studied area covers the eastern part of the Domažlice crystalline complex, consisting of the Kdyně basic complex and of the Stod granitoid massif. The Kdyně complex is represented by its north-eastern part where the Kdyně massif proper is built of quartz diorite and its crystalline mantle of metabasites represented by various types ol amphibolites whose mafic components are Fe, Mg silicates of the amphibole group and the main accessories are ilmenite and pyrrhotite. Crystalline pelitic-psammitic schists are less abundant. Among them various types of contact hornfelses, sometimes cordieritic, prevail. The Stod massif is built up mainly of biotite granite in which numerous enclaves of quartz diorite and pyroxene-amphibole hornfels occur at the contact with the Kdyně massif.

The study area includes the south-western part of the Barrandian, which with increasing regional metamorphism passes into the rocks of the Domažlice crystalline complex. The boundary between the both units is indistinct and can be defined by the conventional boundary of the biotite isograde.

The lithofacial development of the pelitic-psammitic sediments changes from NW to SE. In this direction the frequency and amount of black (graphitic) schist



1. Scheme of geological units and sample collection localities

1 – Moldanubicum, *2* – Proterozoic, *3* – KI – Kasejovice islet, MI – Mirovice islet, *4* – mafic volcanics and plutonites: β′ – Proterozoic basalts ("spilites"), σ – Kdyně massif, A – amphibolites, *5* – acid and intermediate plutonites, CBM – Central Bohemian Pluton, SGM – Stod granitoid massif, *6* – sample collection localities (*PŠ* symbol in text) intercalations increase similarly as the number of pyrite shists and lydites. The greywackes are separated into individual layers and lenses, between Klatovy and Švihov attaining the thickness of hundreds of meters. The mineral association of metapelites in this area is locally enriched with amphibole.

Facial changes can also be observed in belts of metabasites. The number of bodies primarily corresponding to basalts increases also in the NW—SE direction. Their chemical composition is that of tholeiites. Alkaline basalts of the Domažlice crystalline complex occur westwards, outside the study area.

The rocks, between Blovice and Nepomuk, belong also to the Barrandian, and, similarly as in the environs of Klatovy, they are metamorphosed due to the thermal effects of the Central Bohemian Pluton into various types of hornfelses. The lithofacial development of metapelites is very similar to that between Klatovy and Švihov. Strikingly different, however, is the development of paleovolcanites which, besides tholeiitic basalts, include types ranging to andesite.

The Centıal Bohemian Pluton occupies the prevailing part of the studied area. It is represented by the Klatovy apophysis and by its south-western and southern branched out parts (Kolinec, Hory Matky Boží and Střelské Hoštice apophyses).

The Klatovy apophysis is composed of the Nýrsko biotite granite, the Klatovy biotite-hornblende granodiorite, the Kozlovice biotite-cordierite granodiorite and of marginal-type biotite granite. The petrography of the south-western part of the Pluton is relatively monotonous, composed of the Blatná biotite granodiorite and of the Červená biotite-amphibole granodiorite. In the southern part the Kozárovice (Sázava) biotite-amphibole granodiorite and the porphyritic biotite-amphibole melanocratic granite of Čertovo břemeno occur.

The more important enclaves of the Pluton crystalline mantle in our study area, are represented by the Kasejovice islet, by the Mirovice islet, mainly its southern part formed by the Mirotice orthogneisses, and finally by the southern margin of the Sedlčany—Krásná Hora islet, also composed of the Mirotice orthogneisses.

The Moldanubian part of the study area consists of a lithologically varied complex of rocks. Migmatized paragneisses, sometimes with sillimanite and cordierte, prevail. Intercalations of different rocks comprise quartzites, erlans, crystalline limestones, and amphibolites. Leptynites and orthogneisses can be observed locally.

The local accumulations of various intercalations create in the Šumava section of the Moldanubicum several regional-geological units. From W to E these are: the Strážov varied unit south of Klatovy, the Sušice varied unit, and the Strakonice varied unit. The above mentioned occurrences of migmatites of orthogneises can be ranged to the Podolsko complex.

Local intrusions of granitoid rocks in the Moldanubicum, abundant especially along the contact with the Central Bohemian Pluton, are represented by different types of leucocratic granites, granodiorites and tonalites of the Červená type, and in the eastern part of the area by porphyritic melanocratic Rastenberg granite, which is equivalent to the Čertovo břemeno type of the Central Bohemian Pluton.

Minor Tertiary relics ranged to the South Bohemian basins, occur near Horažďovice, Strakonice and Písek, in a greater extent in the environs of Protivín and Vodňany where they are more or less associated with the Budějovice basin.

As regards Quaternary sedimentation, this is an area of predominant denudation with minor local deposits, chiefly deluviums and alluviums. In the Otava valley, only relatively thin terraces can be observed.

Outline of previous geophysical measurements

Regional geophysical measurements

At the end of the 1950s the entire area of interest was covered by reconnaissance airborne mapping 1 : 200 000. Much more detailed, however, was the airborne geophysical mapping 1 : 25 000 conducted during the 1960s. Measurements of the total magnetic field were carried out using flux-gate magnetometer with the accuracy ranging between 8 and 13 nT. For radiometric measurements scintillation counter was used.

The entire area of interest was also covered by gravity mapping 1 : 200 000, some parts on the scale of 1 : 50 000.

Physical properties of rocks

The previous petrophysical studies in the area concentrated on the Kdyně-Štěnovice magnetic anomaly. Physical properties of so called spilites in the area were studied by Čejchanová (1971).

Krsová (1976) measured magnetic properties of a set of rock samples from the so called Přeštice zone of the Kdyně-Štěnovice anomaly.

Chlupáčová (1984) studied magnetic properties of rocks in a gallery and in a horizontal drillhole at the locality Struhadlo in the Přeštice magnetic zone. She found out that the magnetic susceptibility characterized the pyrrhotite distribution. The study of magnetic anisotropy implies that magnetic and metamorphic foliations are interrelated and presumably formed by the same deformation. It implies that the pyrrhotite mineralization was pre-deformational or perhaps syndeformational owing to the forming of metamorphic foliation.

In other parts of the area of interest physical properties of rocks were studied separately at individual localities. Physical properties of rocks of the Kasejovice islet were examined by Hron (1963), who collected 75 samples from anomalous magnetic zones and measured their susceptibility and density. Samples described as quartzitic hornfelses exhibited large values – susceptibility 20.5×10^{-3} to 431×10^{-3} SI units, density 2.82 to 3.03 g . cm^{-3}. Amphibolites were strongly magnetic – susceptibility 12.6×10^{-3} to 80×10^{-3} SI units. Orthogneisses exhibited susceptibility values 3.4×10^{-3} to 23.3×10^{-3} SI units. Other rock samples from the Kasejovice islet did not show increased susceptibility.

Physical properties of rocks of the Kasejovice islet and of the Proterozoic spilite series between Sedliště and Starý Smolivec were studied by Krsová and Šťovíčková (1975). Their results show relatively high susceptibility and remanent magnetization of Proterozoic spilitic rocks. The chief carrier of magnetization was found to be pyrrhotite, in places magnetite. The northern part of the Kasejovice islet is characterized by the presence of magnetite in amphibolites, quartzites, and orthogneisses. On the contrary, in the southern part of the islet some amphibolites contain also pyrrhotite. This is what they have in common with the spilite series. It is also manifested by higher mineralogical densities.

Hron (1963) studied the susceptibilities of various types of Moldanubian orthogneisses from the area of Hartmanice. The obtained values ranged from 0.2×10^{-3} (two-mica sillimanite paragneiss) to 9.2×10^{-3} SI (biotite feldspathized paragneiss).

Local geophysical measurements

The relatively large area of approx. 45 km^2 between Sedliště and Starý Smolivec where the Proterozoic spilite series contacts on the Klatovy apophysis was surveyed by Benda (1973). The network of profiles at 100 m intervals and points at 20 m intervals made it possible to delimit with sufficient accuracy the individual magnetic anomalies. Results can serve for comparison of ground and airborne measurements.

Ground radiometric measurements

Almost the entire study area was covered by a systematic radiometric survey carried out by Uranový průzkum Liberec. Emanometry prevailed namely in the 1950s when it was applied on the scale of 1 : 25 000 (with 250 m intervals between profiles) and in more perspective area on the scale of 1 : 5 000, in places on even more detailed scales. Since the 1970s the survey concentrated on selected localities (1 : 5 000), radiometric sounding moved to greater depths and the gamma method spread. Attention focused mainly on the Klatovy apophysis in the Central Bohemian Pluton, on its north-western exocontact and on the Chanovice apophysis.

Since the 1970s ground gamma spectrometry has been applied on parametric profiles in order to verify the distribution of radioactive elements in the Central Bohemian Pluton and in adjoining geological units, and to estimate the known anomalies of total radioactivity and emanation. At first the measurements were executed in dug holes, later on in drilled holes 150 mm in diameter, predominantly in eluvial-deluvial covers.

New airborne geophysical survey

Airborne magnetometric and gamma spectrometric survey was carried out using the proton magnetometer G 801/3 B (Geometrics) and the difference four-channel gamma spectrometer DiGRS 3001 (Exploranium).

The magnetometer detector is mounted at the edge of the right wing of the aircraft. Detectors of the gamma spectrometer are eight NaI(Tl) crystals of the total volume of 14 830 cm^3 which are placed inside the aircraft.

The equipment comprises electronic navigation system Mini Ranger III, Motorola, which enables navigation of the aircraft along the planned path, digital recording of the local coordinates of the points of measurements and calculation of the real flight path. Owing to the accurate location the quality of the resultant geophysical maps is greatly increased. A limiting factor of the electronic navigation, however, is the condition of direct visibility between the aircraft and two ground reference stations. Where this is impossible, the aircraft must be navigated by the navigator and the coordinates are interpolated using orientation points that he has chosen. Then, of course, the accuracy of locating the measured data is decreased.

Of basic importance for the airborne survey is the field verification system which was used together with the desk-computer Olivetti M 20. The system enables immediate processing of daily measurements on test profiles, processing of diurnal variations and their introduction to the measured values, subtraction of the background and reduction for altitude.

Furthermore, in all channels on all measured profiles the obtained data were tested for gross errors. Simultaneously, flight paths were checked. The system as a whole enabled daily checks of the quality of measurements.

The entire area was surveyed on the scale of 1 : 25 000, i.e. the flight lines were parallel, at 250 m intervals. Moreover, so called tie lines, perpendicular to the flight lines at 2.5 km intervals, were flown. Measurements on both flight and tie lines were conducted at a ground clearance between 60 and 100 m (the average was 80 m). The velocity of the aircraft ranged from 130 to 140 km per hour. The azimuth of the flight lines was 145° (325°).

Measurements in calibration zones with known concentrations of radio-elements were used to calculate the sensitivities for the given system and altitude of 80 m:

50.0 c.p.s./1 % K (in K-window)
6.0 c.p.s./1 ppm U (in U-window)
2.5 c.p.s./1 ppm Th (in Th-window)
20.0 c.p.s./1 Ur (in TC-window)

The evaluation of daily measurements of the natural gamma spectrometer background showed that in 1983 the variability of radioactivity in atmosphere was favourably low.

Every day the system was checked during flight on a test line. Nevertheless, the accuracy of individual measurements in the study area can be better evaluated by a new method of adjustment of field values on the basis of a network of basic and tie lines. In the point of intersection of a basic and a tie line the obtained values should be equal. The difference between these values is given by the sum of errors of both measurements. By evaluating several tens of thousands of differences obtained at the points of intersection throughout the study area we get the mean error of one measurement as shown in Table 1.

Table 1

Mean error of measurement

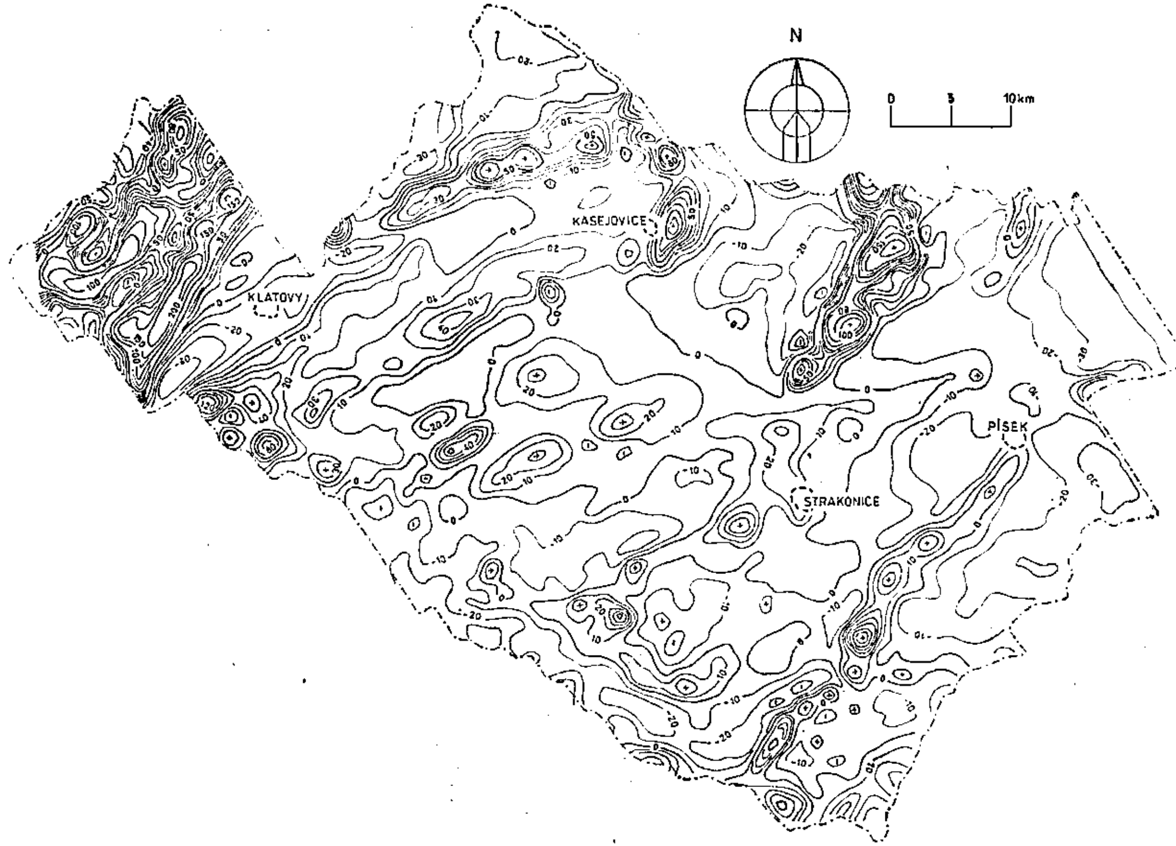
Channel	Mean error of measurement	
	measured quantity	processed quantity
Magnetometry	1.1 – 2.1 nT	1.10 – 2.1 nT
Potassium	4.5 – 6.2 c.p.s.	0.09 – 0.12 % K
Uranium	1.8 – 2.5 c.p.s.	0.30 – 0.4 ppm U
Thorium	1.2 – 1.8 c.p.s.	0.50 – 0.7 ppm Th
Total count	11 – 18 c.p.s.	0.60 – 0.9 Ur

The presented range of mean errors follows from the fact that in some parts of the study area the variability of the measured quantity is small, while elsewhere anomalies are more abundant and thus, naturally, the error of one measurement increases.

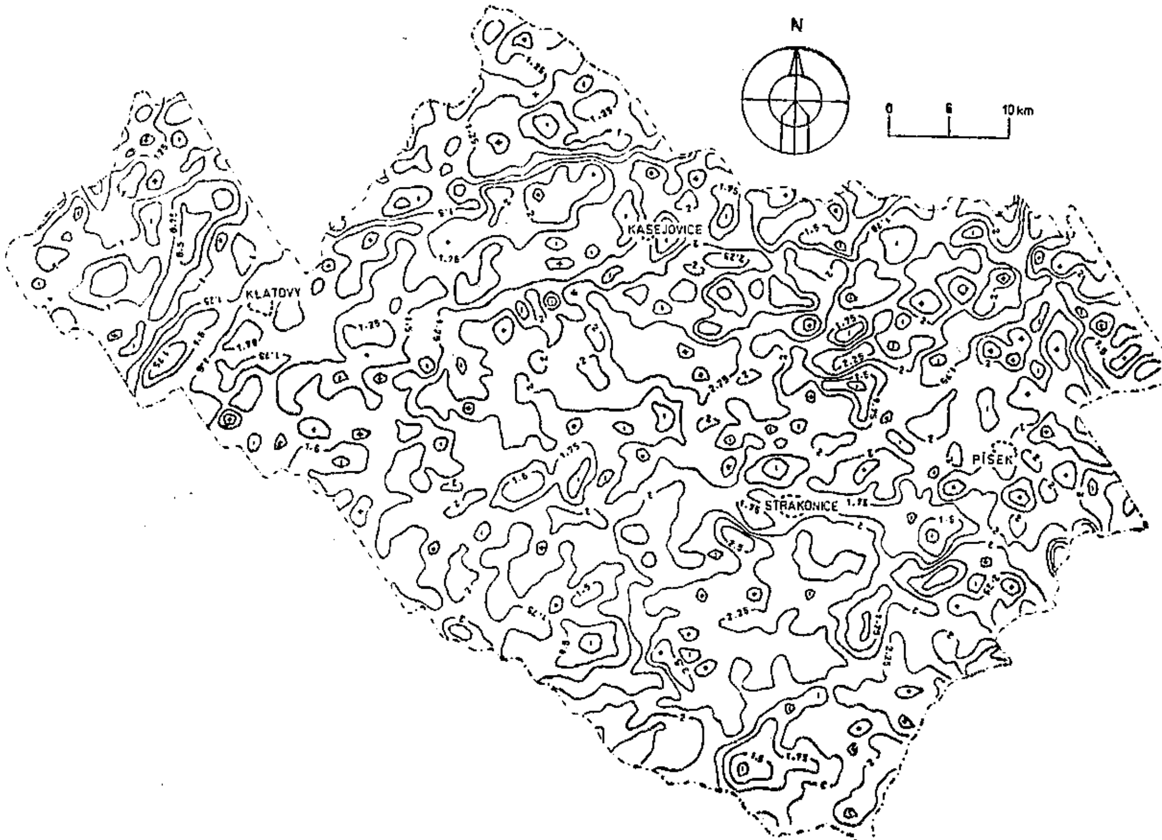
To process the results of measurements and compile contour maps we applied a new method, making full use of navigation data and of an accurate location of the points of measurement.

Observing the planned flight velocity, we take measurements at 35 – 40 m intervals on profiles 250 m apart. The obtained values of magnetic channels are corrected for geomagnetic field diurnal variations, reduced for the normal geomagnetic field and adjusted according to points of intersection of flight and tie lines. Gamma spectrometric values are corrected for natural backgrounds and adjusted according to the points of intersection.

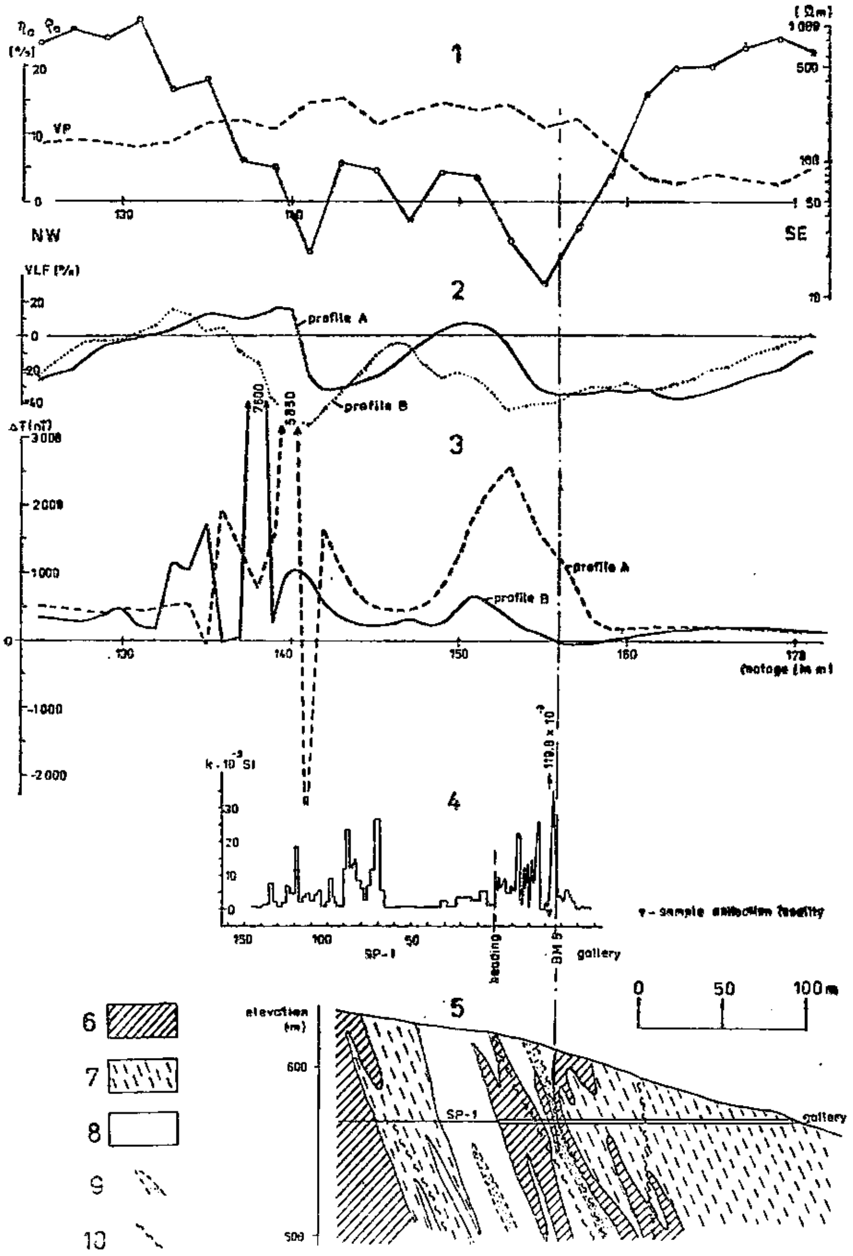
Another important step was evaluating the secular variation between the time of measurement and the epoch 1981. The presented magnetic maps of contour lines are related to the normal field for the epoch 1981.0 for which was used the



2. Airborne magnetometry, analytical continuation of ΔT to the level of 200 m above the flight altitude



3. Airborne gamma spectrometry, concentration of potassium



4. Geophysical profiles above Tetětice gallery

1 – profile A – apparent specific resistivity and induct polarization, *2* – VLF method, *3* – magnetometry, *4* – susceptibility measured in gallery and borehole SP-1, *5* – geological profile, *6* – basalts and metabasites, *7* – greywacke schists and aleurolites, *8* – grafitic schists with metabasite intercalations, *9* – stratiform ore mineralization, *10* – mylonite zones relation

$$T_{1981.0}(\lambda, \varphi) = 48\,012 + 66.7(\lambda - 15) + 262.6(\varphi - 50),$$

where λ is longitude and φ latitude in degrees.

This particular way of data processing employs all the obtained values including location data of the navigation system in order to construct the resultant maps. Thus reliability of results is guaranteed.

The airborne geophysical survey yielded contour maps of the measured parameters and derived magnetic and isoradiation contour maps. Also the maps of analytical continuation of magnetic field upwards to 200 and 750 m above the flight level and the vertical gradient of the analytical continuation of magnetic field at 200 m above the flight level. Radiometric data are presented in the form of contour maps of total count, K, U, and Th concentrations. The K, U, and Th concentrations were used to calculate maps of Th/U, Th/K ratios.

The scale of maps was 1 : 50 000, in some cases 1 : 200 000. The contour map of magnetic field continued upward 200 m above the flight level is in Fig. 2. As an example of radiometric map the contour map of K concentration is shown in Fig. 3.

Ground verification of airborne data

Interpretation of aeromagnetic measurements was based on previous geophysical works, namely reports of Šalanský and Manová (1966, 1974, 1976) and on available geological material. Moreover, to obtain more information we carried out detailed ground geophysical measurements at some anomalies and collected rock samples for petrographic studies and measurements of physical parameters. Interesting results yielded ground measurements over the so called Přeštice anomalous zone near Tetětice (cf. Fig. 4) in the Kdyně-Štěnovice anomaly whose interpretations by various authors differed a great deal.

Geophysical measurements at the locality Tetětice (Struhadlo)

West of Tetětice over the Velký Bítov ridge, measurements were carried out along two parallel profiles A and B situated at a distance of 100 m over a gallery and an underground horizontal borehole SP-1 (Uranový průzkum). The applied methods were magnetometry, the VLF method, symmetric resistivity profiling (SOP), and the IP method. Results of measurements on both profiles projected in the axes of the gallery and of the borehole are in Fig. 4 together with a geological section and with the results of susceptibility measurements by kappameter in the gallery and on cores from the horizontal borehole. The data are taken from the report of Chlupáčová et al. (1984).

According to the geological profile, two high susceptibility zones (Fig. 4) correspond with zones of spilites. The samples collected by Chlupáčová in the high susceptibility zone in the gallery, mostly hornstones and metabasites, have an average Q-coefficient 3.25. The highest susceptibility of approx. 120×10^{-3} SI units was exhibited by a sample of dark metatuff, collected 4 m to the NW of point BM5. Samples from the high susceptibility zone in borehole SP-1, described as hornstones, tuffs and spilitic rocks, have an average Q-coefficient 2.77 and the highest susceptibility is approx. 60×10^{-3} SI units.

The distinct magnetic anomalies detected above the gallery and horizontal borehole were shifted by approx. 30 m to the NW of both increased susceptibility zones, obviously, due to dipping of the strata. The smooth shape of the magnetic anomaly over the increased susceptibility zone in the gallery indicates that the zone does not reach the surface. On the contrary, the increased susceptibility zone in the borehole, approx. 70 m wide, comes out at the surface, as it can be seen from the gradient of the magnetic field which changes from −2 500 nT to +5 850 nT over a short distance (on profile A).

Resistivity and IP measurements were carried out on profile A only, with AB/2 = = 50 m. Both magnetic zones are manifested by decreased resistivity (below 30 Ωm) and by a continuous increased polarization zone (up to 15 %). It shows that the carrier of magnetization is a sulphidic mineralization, i.e. pyrrhotite.

Kovalová and Mrázek (1986) determined the contents of minority elements in the horizontal borehole SP-1. In the high susceptibility zone (66 to 135 m from the face) the contents of economic elements, except for Ag, were lower. It can be said that the pyrrhotite mineralization is basically monomineral.

A comparison of ground geophysical data, petrophysical data from the borehole and from the gallery, and the petrographic descriptions of rocks shows that the source of the anomaly are paleovolcanites (metabasites) with a high content of pyrrhotite.

Ground radiometric verification

In the past few years ground preliminary verification of airborne geophysical maps became an essential part of airborne geophysical mapping. The verification is aimed at better reliability of airborne radiometric maps and at obtaining information about the distribution of radio-elements in eluvial-deluvial covers which is necessary for geological interpretation. Detailed ground verification is carried out by the users of airborne geophysical maps according to their own prospection tasks.

In the course of the airborne survey in Pošumaví we accomplished preliminary verification on 34 ground gamma spectrometry profiles. Moreover, to evaluate the contour maps of K, U and Th concentrations we used data obtained by Uranový průzkum from their own prospection.

On certain parts of the profiles we used ground spectrometers to measure K, U and Th concentrations in boreholes 150 mm in diameter at a depth of 1 m at most, in dependence on local conditions. In this way obtained values mostly represent the concentrations of radio-elements in the eluvial cover.

Some profiles, aimed at verification of the airborne spectrometric data in the cases when preliminary processing cast doubt on its reality, were measured continuously. The detector was carried 50 cm above the ground and apparent concentration values were read at 80 m intervals. In case of disproportions the maps were corrected. In this way obtained concentrations were close to the airborne values.

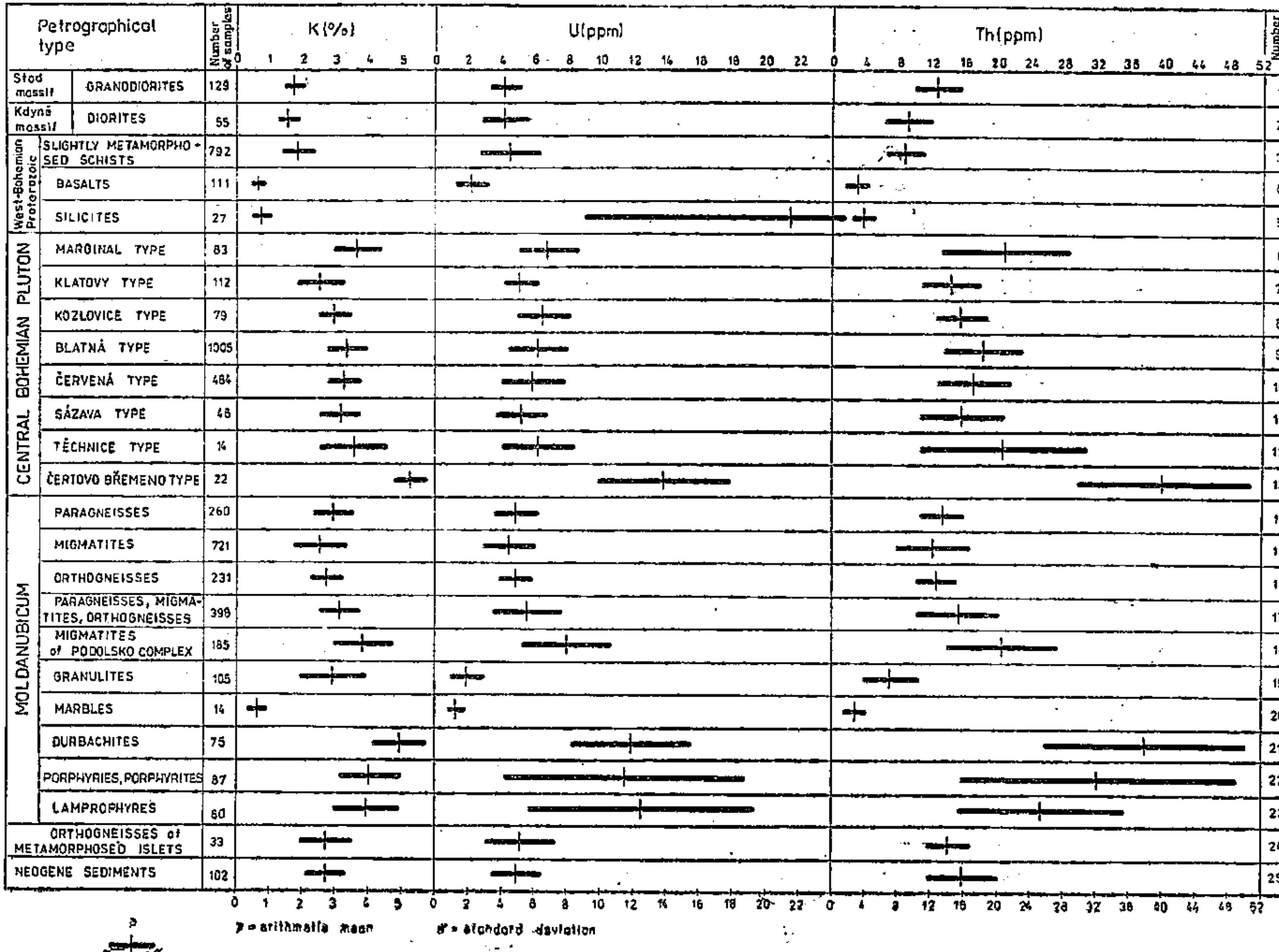
The ground verification showed a good agreement between airborne and ground measurements in a majority of profiles. In a number of cases ground measurements revealed great variability of concentrations which could not be recorded by airborne measurements. Airborne maps show the shielding effect of forests which must be taken into account in interpretation.

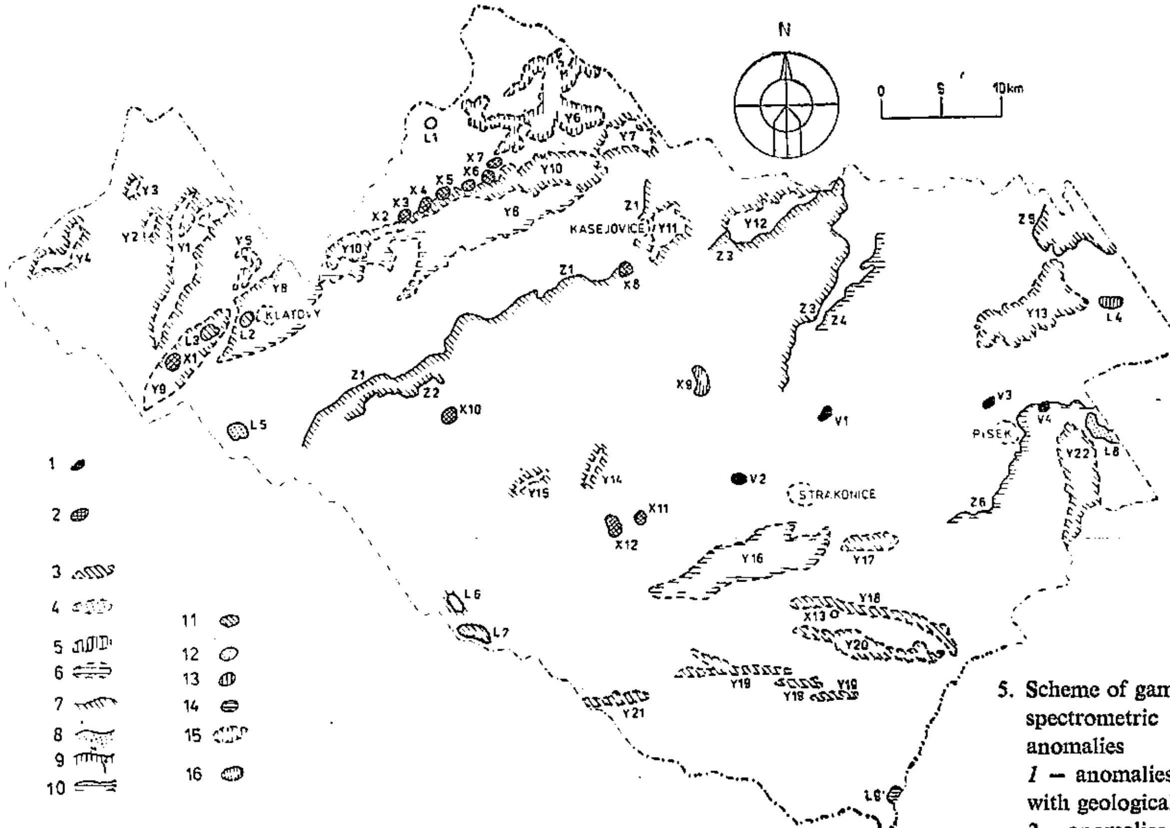
Comparison of K, U and Th concentrations on ground profiles with airborne gamma spectrometric data provided valuable information for geological interpretation of airborne maps.

Ground data were statistically processed (Tab. 2). Average concentrations and other statistical parameters were calculated, characterizing the radiogeochemical distribution in eluvial-deluvial covers, ranging to the main rock types of the study area. Fig. 5 shows radioactive anomalies classified in the following groups:

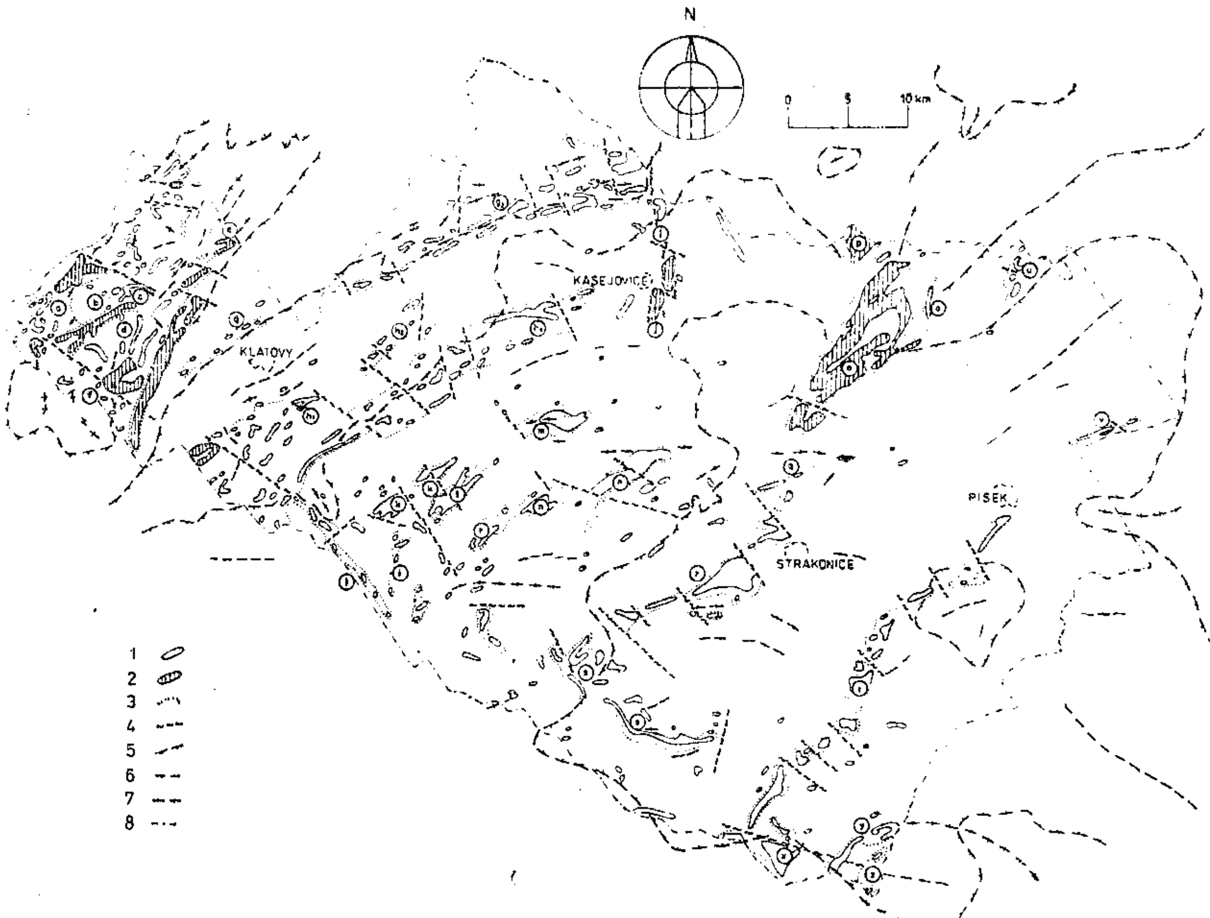
a) Anomalies without geological foundation (Group V) comprise anomalies due to devastation of natural radioactivity field by civilization effects.
b) Anomalies caused by known objects due to spoil material from prospected or exploited localities (Group X).
c) Regional anomalies of concentrations (Group Y) indicate extensive geological units with primary radiogeochemical distribution different from the distribution in neighbouring geological units (e.g. granitoids of the Klatovy apophysis where the concentration of radioelements is increased compared with the surrounding Moldanubian and Barrandian Proterozoic complexes – Y8 or, on the contrary, paleobasalts and crystalline limestones with low contents of radio-elements). Often, the contours of these anomalies do not coincide with the delimited geological boundaries.
d) Regional gradients of concentration (Group Z) indicate important boundaries of rocks with different radiogeochemical distribution (e.g. the north-western boundary of the Chanovice apophysis of the Central Bohemian Pluton with the Moldanubicum – Z1).
e) Local anomalies (Group L) indicate less extensive geological bodies, often of not well defined genesis, with an anomalous radiogeochemical distribution. Some of them can be significant as indications for prospecting for non-radioactive raw materials.

Table 2
Results of statistical evaluation of ground gamma spectrometry





5. Scheme of gamma spectrometric anomalies
1 – anomalies not connected with geological foundation, *2* – anomalies due to the known artificial objects, *3* – multicomponental anomalies, *4* – regional anomalies of K, *5* – regional anomalies of U, *6* – regional anomalies of Th, *7* – regional gradient of concentrations multicomponent, *8* – regional gradient of K, *9* – regional gradient of U, *10* – regional gradient of Th, *11* – local multicomponent anomalies, *12* – local anomalies of K, *13* – local anomalies of U, *14* – local anomalies of Th, *15* – regional anomalies of low values of Th/U ratio, *16* – local anomalies of low values of Th/U ratio. Contours are hatched on the side of higher concentration



6. Scheme of magnetic structures *1* – magnetic anomalies – $\Delta T < 200$ nT, *2* – magnetic anomalies – $\Delta T > 200$ nT, *3* – boundaries of respective magnetic zones, *4* – interpreted tectonic lines, *5* – contours of gravity field, *6* – axes of negative gravity anomalies, *7* – axes of positive gravity anomalies, *8* – boundary of measured area

Interpretation of airborne geophysical survey

Magnetic anomalies

On the basis of magnetic contour maps we constructed a scheme of magnetic structures (see Fig. 6). According to maps of analytical continuation of magnetic field upward to 200 and 750 m we delimited zones including anomalies of the same type. The scheme also shows some important contours of gravity field with indicated directions of the gradients and axes of positive and negative gravity anomalies to make possible comparison of gravity and magnetic data for easier interpretation.

The magnetic field in the surveyed area is greatly varied. The individual geological formations differ by magnetic anomalies, each having a specific character. Distinct in the westernmost part of the study area is the so called Kdyně-Štěnovice anomaly. This area of intensive magnetic anomalies is accompanied by a gravity high and is divided into several partial zones (*a* to *f*). The most distinct and most continuous one is the so called Přeštice zone (*e*) in the east, fringing the Kdyně-Štěnovice anomaly. Results of geophysical measurements and petrographical verification of some anomalies in this area prove that the magnetic anomalies are associated with Proterozoic metabasalts, so called "spilites" with a high content of pyrrhotite, or with rocks of similar genesis, e.g. tuffs and tuffites.

The distinct Žinkovy magnetic zone (g_1, g_2) in the Proterozoic closely follows the north-western margin of the Klatovy apophysis. Occurrences of magnetic metabasites were found in the north-eastern part of the Žinkovy zone (g_2).

The rocks of the Central Bohemian Pluton are practically non-magnetic; some minor anomalies within the Pluton, e.g. zone (*m*) in the vicinity of Břežany, were most probably caused by mantle relics or by younger dyke rocks, or by amphibolite enclaves [zone (*l*) near Hrádek].

Striking anomalies are associated with rocks of the Mirovice islet zone (*o*). The Kasejovice islet zone (*i*) and Staré Sedlo orthogneisses in the southernmost part of the Sedlčany-Krásná Hora islet zone (*u*) are very clearly manifested too.

Approximately NE–SW trending zone of magnetic anomalies can be observed in the Moldanubicum. In Fig. 6 they are designated *h*, *k*, *n*, *q*, *r* and *t*. It can be assumed that they coincide with occurrences of migmatized paragneisses in the Moldanubicum. They do not substantially differ in lithology, but contain more magnetic minerals, presumably of volcanic origin. Most striking of them is the Písek zone (*t*), the northern part of which between Písek and Ražice follows the boundary (Z-6) in Fig. 5 of low K, U and Th concentrations in the northwest and high concentrations in the southeast. Farther to the southwest this boundary can only be assumed because the field of concentrations is disturbed by the presence of other anomalies. This implies that the Písek zone most probably represents zone of metamorphic volcanic rocks, fringing the Podolsko complex, the radioactivity of which is higher compared with the surrounding Moldanubian rocks.

The W–E striking radioactivity anomalies Y-18, Y-19 and Y-20 (Fig. 5) in the area east and south of Volyně are believed to be due to accumulations of dykes of anomalously radioactive porphyries or porphyrites (see below). These radioactivity anomalies fill the gaps in the zone (*t*) magnetic anomalies. The older suite of volcanic rocks of the Písek zone is disturbed by younger E–W striking dykes.

Anomalies of different directions can be observed in the southern part of the study area. They follow mostly the foliation of the Moldanubicum. An exception is the anomalous zone (*s*) whose western part forms a kind of knot from which the anomalies strike in various directions. Obviously, both older and younger tectonic activity left traces there. In the anomalous zone (*x*) submeridional and subequatorial directions play a part besides the NE–SW strike.

As mentioned above, the Central Bohemian Pluton is composed of non-magnetic rocks. However, its tectonic position evidently influences the distribution of anomalies in the area. Magnetic and radioactivity anomalies clearly mark the north-western margin of the Klatovy apophysis. Its south-eastern margin can be traced only in the field of Th-concentrations (anomaly Y-8 in Fig. 5) and does not affect the magnetic field.

An analogy is the Chanovice apophysis from both sides bordered by the Moldanubicum. The magnetic anomalies in the south-eastern margin of zone (h_1) fringe the Chanovice apophysis. It seems that they are linked with the Pluton contact zone. In the field of concentrations of radio-elements as well the north-western margin of the Chanovice apophysis is indicated by the distinct boundary Z-1. The south-eastern margin has not been traced by airborne mapping.

Magnetic anomalies occur also south of Horažďovice in the north-western margin of the Střelské Hoštice apophysis of the Pluton. It suggests that the north-western boundaries of the Pluton are well defined in physical fields and petrophysical properties of rocks change there. On the contrary, south-eastern boundaries cannot be definitely traced by geophysical measurements in the study area. Since, there are practically no petrophysical contrasts between the rocks of the Pluton and of the Moldanubicum.

These facts presumably reflect the tectonic features of the Pluton. It is not easy to explain this asymmetry from geophysical viewpoint. It may be associated with the emplacement of the Pluton which obviously was not vertical. The anomalies of the Petrovice zone (*j*) also delimit the zone of the emplacement of granodiorite bodies, in this case in NW–SE direction.

In the south-eastern corner of the study area near Husinec the arcuate zones of magnetic anomalies (*y*, *z*) follow the margin of a granulite body.

Results of gamma-ray spectrometry

Radioactivity of the rocks in the investigated area is much varied. The geological units there mutually differ in the distribution of radio-elements. The different concentrations are due to the different origins of geological units and to the primary contrasts in composition of prevailing types of rocks. While a majority of magmatites of the Central Bohemian Pluton belong to felsic rocks with relatively high K-concentrations and associated Th and U-concentrations, the weakly metamorphic Proterozoic sediments and volcanites range to rocks with low concentrations of these elements. Then, radioactivity of the metamorphites of the Šumava Moldanubicum is on average lower compared with granitoids of the Central Bohemian Pluton and higher compared with sediments and volcanics of the Proterozoic. Radioactivity of the Moldanubian rocks on average increases from NW to SE. According to Matolín (1970) it is apparently associated with increased K, U and Th concentrations in the metatect component of some migmatized complexes. The generally increased concentrations in the southern part of the Moldanubicum are also due to porphyric and porphyritic dykes with anomalous radioactivity.

In the Proterozoic there prevail rocks with low K and Th concentrations. The average U-concentration is lower than in the Moldanubicum and in the Central Bohemian Pluton. The distribution of radio-elements in both investigated parts of the Proterozoic in the western neighbourhood of Klatovy and in the vicinity of Blovice is rather different, though.

The western neighbourhood of Klatovy between the Klatovy apophysis of the Central Bohemian Pluton, the Kdyně and Stod massifs exhibit the lowest K, U and Th concentrations (zones Y-1, Y-2 and Y-4 in Fig. 5). The relatively monotonous concentrations in weakly metamorphic Proterozoic schists and in the diorite apophysis of the Kdyně massif are contrasted by extremely low values in mafic Proterozoic volcanites. An almost continuous zone of low concentrations Y-1 coincides with the Kdyně-Štěnovice magnetic anomaly and indicates a large body of mafic paleovolcanites. Increased K, U and Th-concentrations, without contrasts however, can be observed in the southern part of the Stod massif (zone Y-3).

Several local anomalies occur in low K- and Th-concentrations in the vicinity of Blovice. Greater differences can be observed between U-concentrations where numerous local anomalies (X-2, X-1) occur. It can be assumed that the generally increased and varied U-concentrations were affected by numerous inclusions of rocks with anomalous U-concentrations (particularly silicites) and by secondary redistribution of U.

Majority of granodiorites in the Central Bohemian Pluton exhibit similar K, U and Th-concentrations. Therefore, also their indications in airborne maps are analogous. In the area of the Klatovy apophysis marginal type granites and granodiorites (Y-9 and Y-10) differ from the remaining granitoids (Y-8) by higher K, U and Th-concentrations. As it can be seen in radiometric maps, the contours of the anomalies deviate from the geological boundaries of these rocks, namely where the Klatovy apophysis links with the Central Bohemian Pluton. According to airborne maps the marginal granites do not occur there.

Both contacts of the Klatovy apophysis and the south-western contact of the Chanovice apophysis (Z-1) relatively distinctly differ from their neighbourhood. Similarly as in the magmatites of the Klatovy apophysis, the K, U and particularly Th-concentrations in the Blatná granodiorite are higher than in the surrounding rocks and compared with the Moldanubicum their contrasts are big enough to enable drawing of the boundary. On the contrary, the south-eastern boundary of the Central Bohemian Pluton, cannot be easily interpreted on the basis of concentrations because of a gradual decrease of concentrations in the Central Bohemian Pluton towards its southern margin. Moreover, interpretation of the southern margin of the Pluton is influenced by random locations of shielding forests. The Blatná granodiorite contrasts with the metamorphic islets of Kasejovice (Y-11) and Mirovice (Z-3). The highest concentrations of radioactive elements within the Blatná type coincides with its porphyric facies in the vicinity of Blatná.

East of the Mirovice islet high concentrations are exhibited by durbachite of the type of Čertovo břemeno near Sobědraž (Z-5). The occurrence of this type near Vráž (Y-13) is also manifested by anomalous K, U and Th-concentrations. According to airborne maps these concentrations outcome the extent of the assumed geological body.

Concentrations of radio-elements in most of Moldanubian rocks are very similar. Therefore in airborne radiometric maps it is impossible to distinguish paragneisses from orthogneisses. From NW to SE the radioactivity of both para- and ortho-series gradually increases. In the eastern part the high concentrations (Z-6) are obviously associated with migmatites of orthogneiss appearance of the Podolsko complex. Extremely high concentrations in the vicinity of Písek indicate a durbachite body (Y-22).

As seen in radiometric maps, the lowest concentrations in the Moldanubicum coincide with occurrences of crystalline marbles (Y-14, Y-14), e.g. the well known bodies in the vicinity of Rábí. A total decrease of concentrations can be observed in some parts of the varied group with numerous marble occurrences. Striking E – W trending linear anomalies (Y-17 to Y-20) in the area delimited by Kašperské Hory, Volyně, Bavorov and Vimperk are due to accumulations of parallel dykes of porphyries and porphyrites. They indicate disjunctive tectonic structures of regional significance. Some of them can be traced in airborne radiometric maps at a length of several tens of kilometers. According to the magnetic contour map we can assume that they dislocate the Písek metavolcanic zone. On the contrary, partial discontinuities may indicate younger disjunctions, presumably striking to the NE. Results of statistical evaluation of the ground spectrometric survey are given in Tab. 2.

Petrophysical and petrological characteristics of aeromagnetic anomalies

Field samples were collected during the summer and autumn of 1984. Owing to the large extent and to geological diversity of the study area we were not able to carry out field reconnaissance of all detected magnetic anomalies. Therefore we focused on expressive anomalous zones and on some significant anomalies, regardless of previous studies. We did so in an effort for overall understanding, also taking into account the preceding stage of airborne measurements, namely in regard to the original petrophysical interpretation of important aeromagnetic anomalies. Measurements by KT-5 kappameter were taken in the broader surroundings of the anomalous maxima on all rocks from outcrops and artificial exposures, from skeletons in fields, pastures and forests, and on loose boulders and blocks which presumably had not undergone transport. We executed tens to hundreds of measurements at every locality and collected representative samples of autochthonous maximally magnetized rocks and for comparison samples of less magnetic or non-magnetic rocks. At 62 localities (Fig. 1) we collected 148 samples for laboratory studies – determination of bulk and mineralogical density (σ_o and σ_m), porosity (p), magnetic susceptibility ($\varkappa$), remanent magnetization intensity (J_r) and calculation of the Koenigsberger ratio (Q-coefficient). The values of physical properties of respective samples (*PŠ 1-62*) of microscopically identified rocks are listed in Table 3. At another 23 localities we did not found either any rock material at all (because of thick, either Quaternary or Tertiary, cover), or only non-magnetic rocks.

Subsequently, we microscopically examined all samples with the aim to identify rocks types and carriers of anomalous magnetization. We believe that this very approach to interpretation of anomalies with evidently surface sources yields realistic results. Of 148 samples collected at 62 localities we made 83 thin sections for qualitative petrographic analysis.

Anomalous rocks will be described from W to E, similarly as in the chapter of geology.

1. In the westernmost part the attention was paid to rocks within the Kdyně-Štěnovice anomaly where individual NE – SW striking zones of magnetic anomalies precisely coincide with morphologically apparent belts of Proterozoic basalts (so-called spilites). These basalts are almost non-metamorphosed in the south-western part of the Barrandian and both regionally and thermally metamorphosed in the Domažlice crystalline complex. We attempted to elucidate this zone, one of the most significant magnetic zones in the Bohemian Massif, whose previous interpretations had been somehow confused.

In the major metabasalt belt contoured by the Přeštice anomaly in the area Zdeslav – Chudenice – Ježovy the predominant magnetized rocks are weakly regionally metamorphosed basalts (metaspilites) – *PŠ 45, 46, 47, 48, 50* and *51* (of Table 3). They are identified as greenschists with chlorite and actinolite often with striking relic structure of original basalts and their tuffs (with clearly recognizable compressed pyroclastic clasts, maybe plastic at the time of deposition, partly dynamometamorphosed). They contain actinolite, chlorite, clinozoisoite, albite, calcite. Lava equivalents contain phenocryst palimpsests. An ore-component is ilmenite, but the predominating ferromagnetic mineral is pyrrhotite, often forming macroscopically recognizable impregnations. It is present in the form of small grains in the ground mass, they often mobilize and create tiny veinlets.

We have never observed that it would originate from pyrite. Magnetic susceptibility of metaspilites in this zone attains $0.82-5.12\times10^{-3}$ SI. The Q-coefficient is generally more than 20. The maximum remanent magnetization value is 9 871 nT. The north-western belt of metabasalts between Kdyně and Koloveč which underwent intensive regional and contact metamorphism is the source of linear, though dispersed, anomalies. The collected magnetized samples *PŠ 52, 53, 56, 57* and *58* are metabasalts metamorphosed, however, even to pyroxene-amphibole hornfelses with mosaic or poikiloblastic structure almost without relics of original lava or pyroclastic structures. The association comprises green amphibole, brown or orange granoblastic or nematoblastic amphibole, pyroxene of salite nature, fresh non-lamellar plagioclases, titanite, apatite, ilmenite, and above all pyrrhotite. Magnetic susceptibility ranges from 0.67 to 6.11×10^{-3} SI. The Q-coefficient is mostly high. Remanent magnetization values attain up to 29 000 nT. This belt also includes the diorite bodies of the Kdyně complex which, sporadically, are the sources of anomalies. It is e.g. amphibole-pyroxene-biotite diorite up to quartz diorite (*PŠ 52b* – $\varkappa = 2.22\times10^{-3}$ SI, Q = 5.94) where the only ore mineral found was ilmenite (or titanomagnetite), similarly, in the southernmost belt between Libkov, Loučim and Tetětice (including the locality Struhadlo studied by Chlupáčová et al. 1984) metaspilites (greenschists – *PŠ 59a*) strongly impregnated with pyrrhotite ($\varkappa = 7.42\times10^{-3}$ SI, I_{rn} = 15 864 nT) as well as pyroxene-amphibole diorites with titanomagnetite (*PŠ 60b* – $\varkappa = 11.61\times10^{-3}$ SI, Q = 4.5) occur. A reliable identification property of all metabasites is their high mineralogical density, mostly around 3.0 g . cm^{-3}. It can be concluded that the magnetic anomalies in the south-eastern margin of the extensive Kdyně-Štěnovice zone are presumably due to pyrrhotite primarily associated with Proterozoic basaltic volcanism regardless of the degree to which it had been affected by younger regional and/or contact metamorphic processes as it is evidenced by high remanent magnetization values of almost all paleobasalt samples of various metamorphic degrees.

2. The rocks of the Central Bohemian Pluton in the study area do not reveal anomalous magnetization. An exception is e.g. foliated amphibole-biotite granodiorite, containing magnetite, in the Střelské Hoštice apophysis (*PŠ 32* – $\varkappa = 25.44\times10^{-3}$ SI). It is presumably an assimilated remnant of the mantle, i.e.

Table 3

Review of anomalously magnetized rocks and of their petrophysical properties

Number of sample ($P\check{S}$)	Locality	$\varkappa$ (10^{-3} SI)	Q coef.	σ_m (g.cm^{-3})	Lithology	Carrier of magnetization
1a	Cehnice	24.32	0.19	2.69	amphibole-biotite orthogneiss	magnetite
1b	Cehnice	28.83	0.27	2.68	leucocratic biotite gneiss	magnetite
1d	Cehnice	16.79	0.21	2.69	leucocratic biotite gneiss	magnetite
1e	Cehnice	68.90	0.11	3.00	diopside amphibolite	magnetite
2a	Kváskovice	24.02	0.19	2.69	amphibole-pyroxene leptynite	magnetite
2b	Kváskovice	24.42	0.26	2.68	leucocratic biotite-amphibole orthogneiss	magnetite
2c	Kváskovice	87.36	0.07	2.89	amphibolite	magnetite
4a	Střítež	59.96	0.26	2.83	amphibole-biotite paragneiss	magnetite
4b	Střítež	40.53	1.10	2.87	biotitic amphibolite	magnetite
4c	Střítež	22.76	0.16	2.41	biotite-plagioclase paragneiss arteritic migmatitized	magnetite
5b	Litochovice	30.47	0.30	2.70	biotitic arteritic migmatite	magnetite
6b	Kobylence	44.91	0.19	2.89	migmatitized amphibolite	magnetite
6d	Kobylence	19.41	0.13	2.76	quartz-amphibolite	magnetite
6e	Kobylence	18.50	0.32	2.69	biotite orthogneiss	magnetite
7	Volyně (Bohunice)	60.94	0.10	2.76	magnetitic biotite paragneiss	magnetite
10a	Bušanovice	46.66	4.92	2.96	amphibolite	magnetite Q > 1
11c	Beneda (Zálezly)	7.22	0.38	2.65	leucocratic biotite orthogneiss to leptynite	magnetite

12b	Beneda	52.74	0.49	2.85	migmatitic amphibolite	magnetite
12c	Beneda	111.14	0.20	2.96	altered pyroxene amphibolite	magnetite
13a	Vlachovo Březí	0.38	0.36	2.78	biotite-cordierite paragneiss (mobilizate portion)	pyrrhotite
13c	Vlachovo Březí	203.60	1.30	2.89	biotite-cordierite gneiss	magnetite
15b	Husinec	3.24	2.08	3.44	garnet-amphibole skarn	pyrrhotite
17b	Žárovná	5.49	20	2.67	leucocratic biotite orthogneiss	unknown
17c	Žárovná	2.50	1.62	2.67	biotite orthogneiss	
17e	Žárovná	35.29	0.70	2.74	quartz amphibolite with biotite and garnet	magnetite
18	Šumavské Hoštice	5.88	1.28	2.74	biotite porphyrite up to kersantite	magnetite
19b	Mirotice	27.513	0.16	2.66	biotitic orthogneiss (Mirotice type)	magnetite
20a	Stráž	5.39	0.13	2.64	leucocratic biotite orthogneiss	magnetite
20b	Stráž	55.75	0.11	2.78	biotite metaporphyrite	magnetite
20c	Stráž	57.58	0.12	2.97	granitized amphibolite	magnetite
20d	Stráž	96.58	0.29	2.82	two-mica paragneiss	magnetite
21a	N of Mirotice	21.72	0.26	2.68	amphibole-biotite quartz diorite	magnetite
21c	N of Mirotice	6.47	0.36	2.66	muscovite-biotite aplite	magnetite
21d	N of Mirotice	37.85	0.32	2.75	biotite-amphibole quartz porphyrite (dacite)	magnetite
25a	Přečín	7.44	0.17	2.73	pyroxene-amphibole-biotite erlan gneiss	magnetite
25b	Přečín	27.26	0.11	2.69	biotite quartzitic gneiss with garnet	magnetite
25c	Přečín	31.99	0.26	2.71	biotite-amphibole-pyroxene quartzitic erlan gneiss	magnetite
25d	Přečín	14.82	0.10	2.75	pyroxene-amphibole quartzitic gneiss	magnetite
26a	Vacov (Kůstrý)	43.04	3.35	2.81	quartz amphibolite with biotite	magnetite $Q > 1$
26b	Vacov (Kůstrý)	19.48	2.87	2.79	cordierite-biotite-sillimanite paragneiss	magnetite $Q > 1$
26d	Vacov (Kůstrý)	69.57	0.10	2.74	biotite migmatitic gneiss	

Table 3 (continued)

Number of sample (*PŠ*)	Locality	$\varkappa$ (10^{-3} SI)	Q coef.	σ_m ($g.cm^{-3}$)	Lithology	Carrier of magnetization
27a	Nahořánky	35.31	1.00	2.80	cordierite-biotite-sillimanite gneiss muscovitized	magnetite
27b	Nahořánky	21.88	0.13	2.72	migmatitic amphibole	magnetite
27d	Nahořánky	16.80	0.22	2.80	cordierite-biotite-sillimanite migmatitic gneiss	magnetite
27e	Nahořánky	9.45	0.16	2.77	biotite-sillimanite gneiss altered and migmatitized (mobilizate)	magnetite
29b	Parýzek	67.28	2.23	2.79	two-mica sillimanite paragneiss with garnet migmatitized and cataclastic	magnetite Q > 1
29c	Parýzek	71.05	0.19	2.77	biotite-sillimanite paragneiss migmatitized	magnetite
30a	Soběšice	56.13	0.40	2.70	biotite migmatite of orthogneiss appearance	magnetite
30b	Soběšice	82.61	0.29	2.77	biotite-cordierite gneiss migmatitized	magnetite
30c	Soběšice	3.70	0.08	2.75	sillimanite-cordierite-biotite paragneiss	magnetite
30d	Soběšice	47.18	0.08	2.74	amphibole-biotite orthogneiss	magnetite
32	Zádušní les	25.44	0.24	2.67	amphibole-biotite leptynite granitized	magnetite
33	Kašperské Hory	15.80	0.10	2.88	sillimanite-biotite paragneiss with hercynite and garnet	magnetite
35a	Ostružná (Sedlo)	11.13	0.23	2.75	diopside-amphibole leptynite up to erlan with garnet and biotite	magnetite
35b	Ostružná (Sedlo)	24.33	0.08	2.71	amphibole-biotite migmatite of orthogneiss appearance	magnetite
35c	Ostružná (Sedlo)	44.40	0.33	2.74	sillimanite-biotite-migmatitic gneiss	magnetite
36	Albrechtice	14.25	0.94	2.82	sillimanite-biotite paragneiss	magnetite
37b	Sušice (Rok)	13.17	2.86	2.76	cordierite-sillimanite-biotite paragneiss	magnetite Q > 1
37d	Sušice (Rok)	24.10	0.16	2.80	cordierite-sillimanite-biotite paragneiss	magnetite

38	Lešišov	16.66	0.08	2.92	diopside amphibolite	magnetite
39a	Nemilkov	1.30	8.21	2.84	biotite-amphibole-diopside erlan	pyrrhotite
40a	Nalžovské Hory	16.26	0.30	2.67	leucocratic biotite orthogneiss	magnetite
40b	Nalžovské Hory	9.78	0.17	2.70	amphibole epidotic quartzitic erlan	magnetite
40c	Nalžovské Hory	64.81	0.10	3.02	amphibolite	magnetite
41a	Radomyšl	5.65	0.31	2.62	leucocratic amphibole orthogneiss	magnetite
42c	Doubravice	41.25	0.26	2.94	amphibolite	magnetite
42d	Doubravice	35.24	0.14	2.94	amphibolite	magnetite
44a	Radimovy	38.16	0.11	2.62	leucocratic aplitic biotite orthogneiss	magnetite
45a	Chlumsko	5.12	20	3.04	chlorite-actinolite greenschist (spilitic metatuff)	pyrrhotite
47	Krušce	2.39	18.50	3.05	altered metabasalt	pyrrhotite
49	Bělýšov	2.51	20	3.03	amphibolite metabasalt with relic texture	pyrrhotite
52a	Koloveč (Zíchov)	3.09	20	3.01	amphibole hornfels (metabasalt)	pyrrhotite ilmenite
52b	Koloveč (Zíchov)	2.22	5.94	2.91	amphibole-pyroxene-biotite diorite up to quartz diorite	ilmenite
53a	Koloveč (Suková hora)	0.85	0.96	3.03	pyroxene-amphibole hornfels	pyrrhotite
53b	Koloveč (Suková hora)	3.88	20	3.01	diopside-amphibole hornfels	pyrrhotite
56d	Koloveč	4.65	14.93	2.96	actinolite contact greenschist (basaltic metatuff)	pyrrhotite
57	Němčice	6.21	20	2.98	pyroxene-amphibole hornfels	pyrrhotite ilmenite
59a	Libkov	7.41	20	3.11	chlorite-actinolite greenschist (metabasalt)	pyrrhotite
60b	Libkov	11.47	4.58	3.02	pyroxene-amphibole diorite	ilmenite titanomagnetite
62	Kolinec (Vidhošť)	7.67	20	2.88	diopside-amphibole erlan	pyrrhotite

original leptynite. Sample PŠ 38 from the Hory Matky Boží apophysis belongs to an enclave of pyroxene amphibolite with magnetite ($\varkappa = 16.66 \times 10^{-3}$ SI), similarly as numerous rocks from locality PŠ 40 near Čejkovy (Table 3) are mantle enclosures in surrounding plutonites, in this case leucocratic biotite orthogneisses, quartzitic erlans and amphibolites, all of them containing accessoric up to abundant magnetite.

3. Islets zone rocks constitute one of the most important sources of anomalies in the study area. In many cases they were the subject of previous petrographical-petrophysical studies. For instance, in the Kasejovice metamorphic islet (Krsová – Šťovíčková 1975) various types of rocks exhibit anomalous magnetic values: quartzites with magnetite, biotite-muscovite orthogneisses, leucocratic orthogneisses, hornfels paragneisses, various types of amphibolites mostly containing magnetite, often, particularly in the southern parts of the Kasejovice islet, containing pyrrhotite.

The southern part of the Mirovice islet fringed by striking anomalies has recently been studied (*PŠ 19, 20, 21, 22*). Not only the mentioned Mirotice orthogneisses, but also the rocks of diorite to gabbrodiorite composition exhibit anomalous magnetization. Thy typical Mirotice orthogneisses are of the nature of leucocratic biotite or non-mica orthogneisses in association with biotite, acid plagioclases, quartz, orthite, titanite and magnetite (*PŠ 19b* – $\varkappa = 27.51 \times 10^{-3}$ SI, Q = 0.16; *PŠ 20a* – $\varkappa = 5.39 \times 10^{-3}$ SI, Q = 0.13). Biotite metaporphyrite *PŠ 20b* contains altered phenocrysts of plagioclases, zonal, with Baveno twinnings, in the ground mass biotite, plagioclases and magnetite ($\varkappa = 55.75 \times 10^{-3}$ SI, Q = 0.11). Biotite-amphibole quartz porphyrite *PŠ 21d* is characterized by phenocrysts or aggregates of dark minerals (amphibole and biotite), phenocrysts of automorphic zonal plagioclases, very fine-grained ground mass composed of feldspar, quartz, titanite and magnetite ($\varkappa = 37.85 \times 10^{-3}$ SI, Q = 0.32). Amphibole biotite quartz diorite up to granodiorite *PŠ 21a* in addition contains orthite, zircon and ample magnetite ($\varkappa = 21.71 \times 10^{-3}$ SI, Q = 0.26). Amphibole gabbro with phenocrysts of altered plagioclases *PŠ 20c* has a high content of magnetite ($\varkappa = 57.58 \times 10^{-3}$ SI, Q = = 0.11). Of the collected samples paragneiss with association of biotite, muscovite, plagioclases, quartz, magnetite (*PŠ 20d* – $\varkappa = 96.58 \times 10^{-3}$ SI, Q = 0.29) exhibited the highest magnetization. In the southernmost corner of the Mirovice islet southwest of Sedlice the rocks with highest magnetization are leucocratic and biotite orthogneisses (*PŠ 42a* – $\varkappa = 9.76 \times 10^{-3}$ SI, Q = 0.92; *PŠ 42b* – $\varkappa =$ $= 12.67 \times 10^{-3}$ SI, Q = 0.21) and fine-grained amphibolites with association of green amphibole (up to 40%), plagioclases, rare quartz and ample magnetite (*PŠ 42c* – $\varkappa = 41.25 \times 10^{-3}$ SI, Q = 0.26; *PŠ 42d* – $\varkappa = 35.24 \times 10^{-3}$ SI, Q = = 2.24). Magnetite is the carrier of anomalous magnetization of the Mirovice islet rocks. Majority of the mentioned rocks, both acid and basic, showed characteristic features of originally volcanic structures (porphyritic, very fine

-grained ground mass). They had undergone recrystallization of various degrees, most intensive in the southern corner of the islet (*PŠ 42*).

4. Some Moldanubian crystalline schists, namely of the varied units south of Klatovy, in the broader environment of Sušice, Strakonice, and finally southwest of Písek are the sources of continuous anomalous zones and of numerous minor and major isolated anomalies. Passing again from west to east, within the Strážov unit the main source of local intensive anomalies in the vicinity of Radimovy and Běšiny are metabasic rocks (*PŠ 44b* – banded amphibolites with magnetite – $\varkappa = 76.79 \times 10^{-3}$ SI, Q = 0.17; *PŠ 61a* – feldspar amphibolites with ample magnetite and highest magnetic susceptibility within the entire study area – $\varkappa = 249.72 \times 10^{-3}$ SI, Q = 0.07). However, we also encountered leucocratic biotite orthogneisses with association of chlorite, biotite, plagioclases, microcline, quartz, magnetite, macroscopically resembling erlans (*PŠ 44a* – $\varkappa = 38.15 \times 10^{-3}$ SI, Q = 0.11).

The zone of anomalies north of Nemilkov, of NW–SE direction parallel with elongated minor intrusions of Červená granodiorite remains petrophysically not well explained in spite of very detailed ground geophysical verification. Although samples were collected on all profiles, particularly in their parts crossing zones of anomalies, only one of them exhibited weakly anomalous magnetization: erlan in association with biotite, amphibole, pyroxene, basic plagioclases, titanite, pyrrhotite (*PŠ 39a* – $\varkappa = 1.30 \times 10^{-3}$ SI, Q = 8.21). This is not sufficient for adequate petrophysical explanation – the source of anomaly is probably deep. The belt of anomalies in the Kolinec Moldanubicum near Vidhošť, so far unexplained, is presumably due to the effects of intercalations of erlan with amphibole, diopside, quartz, plagioclases, titanite, pyrrhotite (*PŠ 62* – $\varkappa = 7.67 \times 10^{-3}$ SI, Q > 20).

The minor and major isolated anomalies and continuous zones of anomalies in the Sušice varied group between Sušice and Kašperské Hory have various sources. They are predominantly paragneisses and migmatite gneisses in association with sillimanite, cordierite, biotite, K-feldspar, magnetite, sporadically garnet and hercynite (*PŠ 33, 35c, 36b, 37b, 37d*). The sillimanite-cordierite paragneisses reach magnetic susceptibility values up to 44.4×10^{-3} SI, Q = 0.33 (*PŠ 35c*) and often high mineralogical density values – $\sigma_m = 2.88\ g\,.\,cm^{-3}$ (*PŠ 33* – garnet-sillimanitic paragneiss with hercynite and magnetite). Anomalous magnetization is also exhibited by some migmatites of orthogneiss appearance, with amphibole, biotite, titanite, chlorite, quartz, plagioclases, magnetite and orthite (*PŠ 35b*) as well as rocks of the nature of leptynites and erlans in association with diopside, amphibole, biotite, titanite, garnet, quartz, K-feldspar, and magnetite (*PŠ 35a*). Similar may be the source of another group of striking anomalies, forming an almost continuous NW–SE trending belt between Strašín, Maleč and Přečín NNE of Javorník. The rocks there are cordierite-sillimanite-biotite paragneisses containing quartz, plagioclases, K-feldspar, garnet, zircon and magnetite, often migmatitized and muscovitized (*PŠ 27a, 27d, 29b, 29c, 26d, 26b*). Magnetic susceptibility values vary from $\varkappa = 9.45 \times 10^{-3}$ SI to $\varkappa = 71.05 \times 10^{-3}$ SI at Q = 1, exceptionally Q = 2.23. Densities attain $\sigma_m = 2.80$ g . cm^{-3}. Moreover, anomalous magnetic values are exhibited by quartz and migmatitized amphibolites in association with amphibole, biotite, pyroxene, epidote, titanite, plagioclases, quartz, magnetite (*PŠ 27b* – $\varkappa = 21.88 \times 10^{-3}$ SI, Q = 0.13; *PŠ 26a* – $\varkappa = 43.04 \times 10^{-3}$ SI, Q = 3.35) and finally by pyroxene-amphibole erlan gneisses, often strongly quartzitic with pyroxene, amphibole, garnet and magnetite (*PŠ 25a, 25b, 25c, 25d* – $\varkappa_{max} = 31.99 \times 10^{-3}$ SI). A relatively isolated zone of anomalies ENE of Soběšice is again due to sillimanite-cordierite-biotite paragneisses with magnetite (*PŠ 30b* – $\varkappa = 82.61 \times 10^{-3}$ SI, Q = 0.29; *PŠ 30c* – $\varkappa = 3.70 \times 10^{-3}$ SI, Q = 0.08) and to migmatites of orthogneiss appearance, i.e. amphibole-biotite trondhjemites with magnetite (*PŠ 30a* – $\varkappa = 56.13 \times 10^{-3}$ SI, Q = 0.4; *PŠ 30d* – $\varkappa = 47.17 \times 10^{-3}$ SI, Q = 0.08). W of Radomyšl leucocratic amphibole orthogneisses with epidote, clinozoisite, titanite, orthite and magnetite (*PŠ 41a* – $\varkappa = 5.65 \times 10^{-3}$ SI, Q = 0.31) together with fine-grained amphibolites (*PŠ 41b* – $\varkappa = 15.61 \times 10^{-3}$ SI, Q = 1.18) occur. To the NW of the zone, an isolated anomaly near Katovice is caused by biotite migmatites with high susceptibility (*PŠ 31a* – $\varkappa = 126.23 \times 10^{-3}$ SI, Q = 0.53; *PŠ 31b* – $\varkappa = 62.96 \times 10^{-3}$ SI, Q = 2.89). These samples were strongly weathered and therefore the thin sections could not be made from them. High σ_m values (up to 2.88 g . cm^{-3}) indicate that these rocks are cordierite-sillimanite paragneisses as in many already mentioned cases.

Relatively most samples were collected in the eastern NE–SW trending chain of magnetic anomalies, the so called Písek zone. Only its north-easternmost part could not be verified because of lack of outcrops due to thick cover. First indication in the form of skelet outcrops south of Cehnice are occurrences of leucocratic amphibole-biotite orthogneisses with magnetite, plagioclases, microcline, quartz, apatite, orthite, zircon and epidote (P3 1a, 1b, 1d with maximum magnetic susceptibility $\varkappa = 28.32 \times 10^{-3}$ SI, Q = 0.19) and diopside amphibolites with magnetite (*PŠ 1e* – $\varkappa = 68.90 \times 10^{-3}$ SI, Q = 0.11, $\sigma_m = 3.0$ g . cm^{-3}). In the further continuation of the Písek zone contrast rocks can be encountered: leucocratic biotite-amphibole orthogneisses with magnetite (*PŠ 2b* – $\varkappa = 24.42 \times 10^{-3}$ SI, Q = 0.26) and amphibole-pyroxene leptynites with titanite, orthite and magnetite (*PŠ 2a* – $\varkappa = 24.02 \times 10^{-3}$ SI, Q = 0.19) on the one hand, and amphibolites with magnetite on the other hand (*PŠ 2c* – $\varkappa = 87.36 \times 10^{-3}$ SI, Q = 0.07). At the next locality predominate the biotite-amphibole gneisses with apatite and magnetite (*PŠ 4a* – $\varkappa = 59.96 \times 10^{-3}$ SI, Q = 0.26) and fine-grained biotite paragneisses with magnetite (*PŠ 4c* – $\varkappa = 22.76 \times 10^{-3}$ SI, Q = 0.16). The same rocks occur east of Litochovice (*PŠ 2b* – $\varkappa = 30.48 \times 10^{-3}$ SI, Q = 0.30) and not far from there again migmatitized and quartz amphibolites with magnetite (*PŠ 6b* – $\varkappa = 45.22 \times 10^{-3}$ SI, Q = 0.20) together with biotite orthogneisses (*PŠ 6e*). In the centre of the Písek zone prevail biotite paragneisses with magnetite (*PŠ 7* – $\varkappa = 60.94 \times 10^{-3}$ SI, Q = 0.10), various migmatites of orthogneiss appearance (*PŠ 8* and *9*). The contrasts in composition of rocks with anomalous magnetic values can be observed also in the south-western linear termination of the Písek zone where acid biotite-amphibole orthogneisses to leptynites (*PŠ 10a*, *11c*) and amphibolites and pyroxene amphibolites (*PŠ 10a* – $\varkappa = 46.66 \times 10^{-3}$ SI, Q = 4.92; *PŠ 12b* – $\varkappa = 52.74 \times 10^{-3}$ SI, Q = 0.49; *PŠ 12c* – $\varkappa = 111.14 \times 10^{-2}$ SI, Q = 0.20) both contain ample magnetite. Near Vlachovo Březí similarly as in the Strakonice varied group occur biotite-cordierite gneisses extremely highly magnetized containing abundant magnetite (*PŠ 13c* – $\varkappa = 203.59 \times 10^{-3}$ SI, Q = 1.3). In its southern termination the Písek zone crosses a NW–SE trending zone, similarly as the northernmore Strakonice zone. The sources of anomalies there are analogous: leucocratic orthogneisses (*PŠ 17b* – $\varkappa = 5.49 \times 10^{-3}$ SI, Q = 25.0) and quartz amphibolites with garnet (*PŠ 17e* – $\varkappa = 95.29 \times 10^{-3}$ SI, Q = 0.7). Unfortunately, the high remanent magnetization of the rock was not explained because in thin section any ferromagnetic ore mineral was not found. Noteworthy is the occurrence of garnet-amphibole skarn containing pyrrhotite (*PŠ 15b* – $\varkappa = 3.24 \times 10^{-3}$ SI, Q = 2.08) near Husinec and of dynamically compressed biotite porphyrite to kersantite at the locality Skařez near Šumavské Hoštice (*PŠ 18* – $\varkappa = 5.88 \times 10^{-3}$ SI, Q = 1.28).

Taking into account the given observations it is possible to conclude two interpretational facts: firstly, the clearly zonal, though often irregular, trend of magnetic anomalies and secondly, the defined lithology of rocks occurring in the zones. The dominating trend of seven zones of magnetic anomalies in the entire study area is NE–SW, while part of the Kdyně-Štěnovice zone displays an azimuthal deviation (NNE-SSW). The source of the Kdyně-Štěnovice zone is doubtlessly associated with products of Proterozoic basalt volcanism, more precisely with pyrrhotite genetically connected with it. Moreover, pyrrhotite mineralization occurs also in contact-metamorphic paleobasalts (spilites) at the northern margin of the Klatovy apophysis, in some rocks of the Kasejovice metamorphic islet and rarely in the Moldanubian rocks (e.g. near Nemilkov, Husinec).

The zones of magnetic anomalies in the Moldanubicum are, as a rule, characterized by the presence of magnetized rocks of three kinds: 1. the sillimanite-cordierite-biotite paragneisses containing magnetite and exhibiting the highest mineralogical density within the paraseries; 2. rocks of a relatively very acid nature which may be leucocratic orthogneisses or migmatites of orthogneiss appearance or leptynites with a low content of mafic minerals (amphiboles, pyroxenes, garnet, titanite) and with magnetite, most probably representing metamorphic products of acid volcanic or subvolcanic trondhjemite rocks; and 3. amphibolites with magnetite, sometimes pyroxene-bearing, rarely garnet-bearing often with mineralogical densities only rarely attaining the value of 3.0 g . cm^{-3} typical of amphibolites. The educt of these amphibolites are presumably mafic volcanites in which the content of the light component can be either primary or a product of migmatitization or mutual interaction of products of volcanism of bimodal chemism on linear tectonic zones. The occurrences of both these bipolar types of rocks can be observed, as a rule, at majority of studied localities. It is especially remarkable along the entire Písek belt of anomalies assumed to be a linear zone of contrast volcanites in the NE fringing the Podolsko complex of the Moldanubicum. Occurrences of contrast anomalous rocks can be encountered also in the islet zone, particularly in the Mirovice islet where these rocks evidently have volcanic nature. It is noteworthy (all over the entire study area) that almost all NE–SW trending zones of anomalous magnetization at their southern termination "spread" into perpendicular (NW–SE) anomalous areas, representing some belts of crossing from the southern end of the Kdyně-Štěnovice anomaly to the southern end of the Písek zone. Unfortunately, this perpendicular zone is located at the boundary of the surveyed area and therefore it cannot be accurately delimited.

It can be concluded that in the study area aeromagnetometry indicated several NE–SW trending tectonic zones with occurrences of non-metamorphic and metamorphic paleovolcanites exhibiting anomalous magnetization. The westernmost of them (the Kdyně-Štěnovice zone), according to petrological and petrophysical results, is due to the presence of pyrrhotite genetically connected with products of Upper Proterozoic basalt volcanism. The zone correlates with the linear discontinuity indicated by geophysical data (Pokorný, Šťovíčková, Beneš, 1985) corresponding to the Kladno deep fault (Röhlich, Šťovíčková, 1968). The neighbouring Žinkovy zone of anomalies, on the contrary, strikes from ENE to WSW and according to petrophysical and petrological results is also due to the presence of Proterozoic paleobasalts (mainly contact-metamorphic "spilites"), containing not only pyrrhotite, but also magnetite. This zone correlates with the northern border of the Klatovy apophysis of the Central Bohemian Pluton, and above all with the fault discontinuity detected by geophysics (Pokorný, Šťovíčková, Beneš, 1985), i.e. with the Klatovy deep fault (Röhlich, Šťovíčková, l.c.). Both discontinuities are important gravity linear structures of the Bohemian Massif and in part form the boundary between the Teplá-Barrandian and the Moldanubian blocks. It can be assumed that the significant transport of material from subcrustal portions took place in the Upper Proterozoic. Then the Kladno deep fault evidently acted as an important linear zone of the spreading of the ocean floor with all its attributes including hydrothermal, especially sulphidic mineralization. Pyrrhotite, obviously the primary carrier of anomalous magnetization, is recently regarded as sulphide which might originate at great depths within the Earth body (Anderson, Ahrens, 1986).

Another NE–SW striking linear zones, indicated by magnetometry, occur in the Moldanubian block, but they do not particularly correlate with gravity indication, and, therefore, can be regarded as intra-block zones. They doubtlessly indicate the paleovolcanic linear zones, in some cases several tens of kilometers long. The volcanism is, according to petrological and petrophysical studies, of bimodal character and shows that the crustal (and maybe also subcrustal) structure of this block differs from that of the Teplá-Barrandian block. The anomalous magnetization of this block is, with only few exceptions, due to the presence of magnetite (see Table 3) in metamorphic paleovolcanites, acid or basic. The volcanics of intermediate composition are present with a high probability, too. Their metamorphic equivalents can be the rocks described as paragneisses containing sillimanite, cordierite, hercynite etc. and revealing besides anomalous magnetization higher values of mineralogical densities. They can represent a specific type of high alumina intermediate volcanism, recently described from yong volcanic belts. It is noteworthy that e.g. the zone delimited by anomalies $s-r-q$ (Fig. 6), in the Moldanubicum more or less links up with the distinct zone of anomalies in the Mirovice metamorphic islet. This again draws attention to the recently newly raised problem of stratigraphic classification of the Bohemian Moldanubicum. The most striking of the zones delimited by magnetometry and petrophysics is the Písek zone, the easternmost NE–SW striking linear zone within the study area.

Conclusion

The airborne geophysical survey in southwestern Bohemia was carried out within an investigation of selected parts of the Bohemian Massif.

The quality of measurements and data processing surpassed the previous airborne surveys in Czechoslovakia. In the field was used the verification system based on the Olivetti M 20 computer which enables an immediate check of obtained data. The computer was used on site for processing of check measurements (stability of the instrument, background, test profiles), which also contributed to an increased quality of field works.

Data processing in the computing centre of Geofyzika Brno included a new way of complex data adjustment throughout the entire area of interest, which succeeded in eliminating the differences in measured field levels for individual flight days. Derived maps proved helpful for regional interpretation of the magnetic field.

Ground verification focused on the geological character of the anomalies. Interpretation yielded a lot of information. In some cases the contribution of magnetometry and gamma spectrometry is so important that it can result in changes in the concepts of the structural-geological image of individual parts of the studied area.

In the westernmost part of the area of interest, i.e. in the southern corner of the Teplá-Barrandian block, an expressive zone of magnetic anomalies can be observed, forming the southern part of the so-called Kdyně-Štěnovice first rate anomaly. It consists of several anomalous belts corresponding with decreased K, U, Th concentration zones and mostly correlating with morphological elevations built up by the products of Proterozoic basalt volcanism (the so-called "spilites"). Petrophysical and petrological studies proved that pyrrhotite is the main carrier of anomalous magnetization in these rocks, regardless of the degree of regional or contact metamorphism. Similar character and source has the anomalous belt at the northern boundary of the Klatovy apophysis. In this belt, magnetite in metabasalts also manifests as carrier of magnetization.

The Klatovy apophysis exhibits anomalous radioactivity values. The course of the anomaly indicates that the boundary between the Kozlovice type and the marginal type is different from that shown in previous geological maps.

In the Moldanubicum, south of the Central Bohemian Pluton there are several NE–SW trending zones of anomalous magnetization. They are associated with the so called varied group of the Moldanubicum (Strážov, Sušice, Strakonice units). According to petrophysical and petrological studies the source of these zones are metamorphic products of volcanism of bipolar character. Regardless of their acid or mafic chemism they contain magnetite. Magnetite is also present in rocks of the type of cordierite-sillimanite paragneisses with high mineralogical densities, the educt of which may be also volcanic. Most striking of the magnetic zones of this kind is the Písek zone, which is also due to belt of metamorphic bipolar volcanics, fringing the north-western boundary of the Podolsko complex. In the radiometric pattern, the Podolsko complex is manifested by an increased Th-concentration and the boundary so characterized coincides with the anomalies in the northern part of the Písek zone. In the southern part of the Písek magnetic anomaly the boundary is veiled by the presence of E–W trending anomalies of Th, U and K concentrations. These anomalies are associated with acid dykes obviously indicating younger disjunctive tectonics of regional significance.

In the south-western margin of the study area the orientation of magnetic and some radiometric anomalies radically turns to the NW–SE (direction). It may indicate a linear zone of regional significance, almost over the entire area.

The study area comprises a whole range of metamorphic islets indicated by both magnetometry and radiometry. They are either minor enclaves in the Hory Matky Boží and Střelské Hoštice apophyses of the Central Bohemian Pluton, or the major metamorphic islets (Kasejovice, Sedlčany, Krásná Hora, Mirovice). There again the acid and mafic metamorphic volcanites containing magnetite are the sources of magnetic anomalies.

Airborne gamma spectrometry revealed zones of increased U-concentrations with numerous local anomalies in the Central Bohemian Pluton, in the Moldanubicum between Mirotice and Putim, in the West Bohemian Proterozoic between Blovice and Čížkov.

It should be noted that further occurrences of ore mineralizations may be anticipated not only in the zones of anomalies themselves, but also in some transverse structures disrupting them or even dislocating them. It concerns NW–SE lines as well as E–W lines.

K tisku doporučil Z. Misař
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Letecké geofyzikální měření v jihozápadních Čechách (Pošumaví) a jeho interpretace

(*Résumé anglického textu*)

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Předloženo 22. září 1988

V šedesátých letech a počátkem 70. let proběhla na našem státním území etapa podrobného leteckého geofyzikálního měření – magnetického a radiometrického (úhrnná radioaktivita), která byla po řadu let interpretována v oblasti Českého masívu kolektivem vedeným K. Šalanským.

V rámci nového leteckého geofyzikálního mapování s magnetometrem G801/3B fy Geometrics a gamaspektrometrem DiGRS 3001 fy Exploranium, prováděného s. p. Geofyzika Brno, byla proměřena v roce 1983 oblast Pošumaví.

Do oblasti Pošumaví spadaly z regionálně geologického hlediska jz. cíp středočeského barrandienského proterozoika a přilehlé domažlické krystalinikum s částí kdyňského bazického komplexu, jz. část středočeského plutonu (tj. klatovská a chanovická apofýza), dále metamorfované ostrovy nebo jejich část (kasejovický a jižní část mirovického a sedlčansko-krásnohorského) a konečně krystalinikum českého moldanubika, přesněji jeho pestré jednotky strážovská, sušická a strakonická a v jeho nejvýchodnější části podolský komplex.

Výsledky měření byly zpracovány ve výpočetním středisku s. p. Geofyzika Brno a prezentovány ve formě map izolinií anomálií magnetického pole, úhrnné aktivity gama a koncentrací K, U a Th v měřítku 1 : 50 000 a 1 : 200 000. Počítačové zpracování umožnilo sestavit odvozené mapy magnetometrie (přepočty do různých úrovní) a gamaspektrometrie (poměry koncentrací radioaktivních prvků).

Na základě získaných mapových podkladů byla provedena komplexní interpretace s použitím terénní rekognoskace území a pozemních ověření významnějších magnetických a gamaspektrometrických anomálií. Na řadě magnetických anomálií byly odebrány vzorky hornin a určeny jejich petrofyzikální a petrologické charakteristiky.

Magnetické pole v oblasti Pošumaví je dosti členité a jednotlivé geologické celky se odlišují specifickým charakterem magnetických anomálií.

V nejzápadnější části území je výrazná kdyňsko-štěnovická anomálie tvořena několika více nebo méně pravidelnými zónami (*a* až *e* na obr. 6). Výsledky pozemních geofyzikálních měření i petrofyzikálního ověřování některých anomálií v tomto prostoru jednoznačně ukazují, že magnetické anomálie jsou vázány na proterozoické bazalty, tzv. spility, s vysokým obsahem pyrhotinu, event. na horniny, které jsou s nimi geneticky spjaté, tj. tufy a tufity.

Severozápadní okraj klatovské apofýzy sleduje žinkovská magnetická zóna. Anomálie v jz. části této zóny (g_1) mohou být vyvolány pyrhotinem, vzniklým kontaktní metamorfózou proterozoických kyzových břidlic. V severovýchodní části žinkovské zóny (g_2) jsou vázány na výskyty metabazitů (kontaktních amfibolických rohovců) s magnetitem.

Ve středočeském plutonu v j. výběžku chanovické apofýzy vystupuje anomální zóna *l*, která odpovídá vložkám amfibolitů, a u Břežan nevýrazná zóna *m*, pravděpodobně vyvolaná zbytky pláště plutonu.

Intenzívní anomálie vyvolávají horniny kasejovického (*i*) a mirovického ostrova (*o*). Méně výrazný je projev starosedelských ortorul v j. cípu sedlčansko-krásnohorského ostrova (*u*).

V moldanubiku vystupují jednotlivé zóny magnetických anomálií (*h*, *k*, *n*, *g*, *r*, *t*), které jsou orientovány přibližně ve směru SV—JZ. Nejvýraznější z nich je tzv. písecká zóna (*t*). Severní část této zóny sleduje velmi přesně rozhraní nižších koncentrací K, U a Th na SZ a vyšších na JV. Dále k JZ nelze toto rozhraní sledovat, protože pole koncentrací je komplikováno lokálními anomáliemi. Tato situace nasvědčuje, že písecká zóna sleduje hranici podolského komplexu, který má vyšší radioaktivitu, a ostatního moldanubika.

V jižní části měřeného území se objevují anomálie spíše subekvatoriálních až sz.—jv. směrů. U takové nejrozsáhlejší anomální zóny (*s*) tvoří její z. část jakýsi uzel, ze kterého anomálie vybíhají všemi směry.

Směrově se také odlišuje zóna nevýrazných anomálií (*j*), která sleduje pásmo výstupů drobných granodioritových těles mezi j. výběžky chanovické apofýzy.

Zóny *y* a *z* kopírují kontakt granulitového tělesa.

Z hlediska radioaktivity náleží Pošumaví k oblastem s členitým polem přirozené radioaktivity, přítomné jednotky se vzájemně odlišují distribucí radioaktivních prvků. Zatímco většina magmatitů středočeského plutonu náleží ke kyselým diferenciátům s relativně vysokými koncentracemi K a s tím do značné míry souvisejícími koncentracemi Th a U, náleží slabě metamorfované sedimenty a vulkanity proterozoika k horninám se sníženými koncentracemi těchto prvků. Radioaktivita metamorfitů moldanubika šumavské větve je pak ve srovnání se středočeským plutonem v průměru nižší a ve srovnání s proterozoikem naopak vyšší.

V oblasti proterozoika převládají horniny s nízkými koncentracemi K a Th. Rovněž průměrná koncentrace U je nižší než v oblasti moldanubika a středočeského plutonu. Distribuce radioaktivních prvků v obou zastižených částech proterozoika (v z. okolí Klatov a v okolí Blovic) je přesto poněkud rozdílná.

Západní okolí Klatov mezi klatovskou apofýzou středočeského plutonu, kdyňským a stodským masivem se vyznačuje nejnižším polem koncentrací K, U a Th. Zjištěné extrémní koncentrace odpovídají bazickým proterozoickým vulkanitům. V okolí Blovic je vyšší diferenciace pole koncentrace U, kde se kromě celkového zvýšení nad průměr proterozoika vyskytla řada lokálních anomálií.

Většina granodioritů středočeského plutonu má průměrné koncentrace K, U i Th blízké. V oblasti klatovské apofýzy se od ostatních granitoidů odlišují vyšším polem koncentrací K, U i Th granity až granodiority okrajového typu. Koncentrace odpovídající anomálie se odchyluje od hranic geologicky předpokládaného rozšíření tohoto typu, a to zejména v místech připojení klatovské apofýzy ke středočeskému plutonu, kde se podle interpretace leteckých map koncentrací již okrajové granity neuplatňují.

Oba kontakty klatovské apofýzy i sz. kontakt chanovické apofýzy se od svého okolí poměrně výrazně odlišují. Podobně jako v magmatitech klatovské apofýzy, jsou i v blatenském granodioritu koncentrace K, U a zejména Th vyšší než v okolí a jejich rozdíly proti moldanubiku jsou dostatečně kontrastní pro stanovení průběhu hranice. Naproti tomu hranici červenského typu, který se uplatňuje v kolineckém výběžku a dále podél j. okraje středočeského plutonu až k Písku, není v polích koncentrací možné jednoznačně interpretovat. Příčinou je pozvolné snižování koncentrací ve středočeském plutonu směrem k jeho j. okraji. Blatenský granodiorit se kontrastně odlišuje od metamorfovaných ostrovů mezi Kasejovicemi a Uzeničkami i od z. okraje mirovického ostrova.

Vysokými koncentracemi se jednoznačně odlišuje durbachit typu Čertova břemene u Sobědraže. Výskyt stejného typu u Vráže se rovněž projevuje anomálními koncentracemi K, U i Th, které však podle leteckých map přesahují rozsah odpovídajícího geologicky předpokládaného tělesa.

Koncentrace radioaktivních prvků ve většině moldanubických hornin je velmi blízká, a proto není možné na základě leteckých radiometrických map odlišit pararuly od ortorul a migmatitů. Směrem od SZ k JV se radioaktivita para- i ortosérií pozvolna a mírně zvyšuje. Ve v. části je zřejmá souvislost vyšších konších koncentrací s migmatity ortorulového vzhledu podolského komplexu.

Výrazné v.–z. lineární anomálie v oblasti mezi Kašperskými Horami, Volyní, Bavorovem a Vimperkem jsou způsobeny akumulací paralelních žil, resp. i jednotlivými žílami porfyrů a porfyritů s vysokou radioaktivitou.

Hlavní proterozoický vulkanitový pruh sz. křídla Barrandienu, tzv. domažlicko-kralupský, resp. jeho jz. část, koinciduje zcela přesně s nejintenzívnější magnetickou zónou této oblasti – kdyňsko-štěnovickou magnetickou anomálií. Prostorově koreluje tato anomálie (i její jednotlivé dílčí zóny) přesně s morfologicky nápadnými elevacemi bazaltových paleovulkanitů, a to jak v jejich téměř nemetamorfovaném vývoji v jz. cípu Barrandienu, tak i v metamorfním vývoji v domažlickém krystaliniku. Jsou to tedy jednak velmi slabě regionálně metamorfované bazalty, tj. zelené břidlice s výraznými reliktními strukturami bazaltů a jejich tufů, jednak intenzívně regionálně i kontaktně metamorfované bazalty, tj. pyroxen-amfibolické rohovce bez reliktů původních lávových a pyroklastických struktur. V obou typech je přítomen pyrhotin, udílející jim často vysoké hodnoty remanentní magnetizace (při relativně nízkých hodnotách $\varkappa$ bývá $Q > 20$; tab. 3). Pyrhotin je přítomen nejen jako integrální rudní minerál přímo ve vulkanitech, ale i jako samostatné sulfidické zrudnění na tento vulkanismus nepochybně vázané. Pyrhotin tedy představuje povrchový zdroj anomální magnetizace samotných vulkanitů, ale podle intenzity a charakteru anomálie nelze vyloučit přítomnost subvulkanických i hlubších těles obsahujících i jiná feromagnetika, především magnetit. U této zóny tedy magnetometrie, ale i gamaspektrometrie zřejmě zobrazuje významnou zónu lineární extenzní tektoniky rozpínání proterozoického mořského dna, tj. tehdejší oceánské kůry. Produkty vulkanismu vázané na tuto zónu mají tholeiitový charakter potvrzený deficitem všech tří gamaspektrometricky sledovaných prvků (U, Th, K). Hustoty paleobazaltů jsou dosti jednotné, kromě tufů nikdy neklesají pod hodnotu 3,0 g . cm^{-3}. Nejjižnější anomální zóna v proterozoiku, tzv. žinkovská, sledující z. kontakt klatovské apofýzy středočeského plutonu, koinciduje opět s pruhem kontaktně metamorfovaných paleobazaltů, v nichž je dominantním feromagnetickým minerálem magnetit.

Horniny středočeského plutonu anomální magnetizaci nevykazují. Pokud se v oblasti budované granitoidními horninami vyskytují lokální anomálie, jsou vždy vyvolávány magnetizovanými enklávami amfibolitů, erlanů a leptynitů (zejména v chanovické apofýze a střelskohoštickém výběžku plutonu).

Horniny metamorfovaných ostrovů jsou jedním z nejvýraznějších anomálních zdrojů v oblasti Pošumaví. V kasejovickém ostrovu to jsou kvarcity s magnetitem, dvojslídné a leukokratní ortoruly, rohovcovité biotitické pararuly, amfibolity s magnetitem, pouze v j. části ostrova s pyrhotinem. V jižní části mirovického ostrova jsou to jednak mirotické ortoruly, namnoze leukokratní, jednak horniny dioritového až gabrového složení vesměs s magnetitem. Struktury většiny uvedených hornin jak kyselých tak bazických mají rysy původních vulkanických struktur.

Anomální zóny sv.–jz. směru i jednotlivé anomálie v prostoru strážovské, sušické a strakonické pestré jednotky moldanubika lze vesměs objasnit povrchovými zdroji, tj. anomální magnetizací některých specifických typů krystalických břidlic. Jsou to tyto horninové typy: sillimanit-cordieritické pararuly s magnetitem, místy i hercynitem o vysokých hodnotách $\varkappa = 126 \,.\, 10^{-3}$ SI i vysokých hodnotách σ_m (2,90 g . cm^{-3}), migmatity ortorulového vzhledu až leptynity a erlany a konečně amfibolity, pro něž je příznačný vyšší obsah živců a křemene (tím i relativně nízké hustoty). U všech těchto typů lze předpokládat předmetamorfní vulkanogenní původ. Toto zjištění platí pro všechny anomální zóny, především pro nejvýraznější z nich – píseckou. Je tedy velmi pravděpodobné, že u všech těchto sv.–jz. zón jde o lineární vulkanická pásma hornin kontrastního chemismu od křemenem bohatých trondhjemitických až po bazické, přičemž podíl bazické složky stoupá směrem k JZ. Nositelem magnetizace je magnetit.

Porovnáme-li kontrastní charakter vulkanismu bloku moldanubického s tholeiitovým charakterem vulkanismu sousedního tepelsko-barrandienského bloku, dospějeme znovu nutně k závěru, že tento blok se vyznačuje jinou korovou a pravděpodobně i podkorovou stavbou. Jak skutečnost, že v moldanubickém bloku magnetické anomální zóny vcelku nekorelují s význačnými tíhovými prvky, tak i kontrastní charakter vulkanismu svědčí pro vnitroblokový rozsah a menší hlubinný (nejspíše korový) dosah tektonických struktur leteckou magnetometrií indikovaných. Navíc i tento strukturní pohled opětovně motivuje úvahy o stratigrafickém zařazení pestrých skupin moldanubika v současné době znovu živě diskutované. Především je tím, byť nepřímo, dokumentována větší mocnost kůry v prostoru moldanubického bloku, o které přímo svědčí gravimetrické a seizmické údaje.

Vysvětlivky k tabulkám

Tabulka 1. Střední chyba jednoho měření.

Tabulka 2. Výsledky statistického zpracování pozemní spektrometrie gama. p — aritmetický průměr, σ — směrodatná odchylka aritmetického průměru.

Tabulka 3. Přehled anomálně magnetizovaných hornin a jejich základních fyzikálních vlastností.

Vysvětlivky k obrazkům v textu

1. Zjednodušená geologie a přehled odběru vzorků pro petrofyzikální výzkum.
   1 — moldanubikum, *2* — proterozoikum, *3* — KI — kasejovický ostrov, MI — mirovický ostrov, *4* — bazické vulkanity a plutonity: β' — proterozoické bazalty (spility), σ — kdyňský masív (KM), A — amfibolity, *5* — kyselé a intermediární plutonity, CBP — středočeský pluton, SGM — stodský masív, *6* — lokality odběru vzorků (symbol *PŠ* v textu).
2. Letecká magnetometrie, přepočet pole ΔT do výšky 200 m nad úrovní letu.
3. Letecká gamaspektrometrie, koncentrace draslíku.
4. Geofyzikální profily nad štolou u Tetětic.
   1 — profil A — zdánlivý specifický odpor a vynucená polarizace, *2* — metoda VDV (reálná složka), *3* — magnetometrie, *4* — susceptibilita měřená ve štole a na jádrech z vrtu SP-1, *5* — geologický profil, *6* — spility a amfibolitické metabazity, *7* — drobové břidlice a prachovce, *8* — grafitické břidlice s polohami metabazitů, *9* — stratiformní zrudnění, *10* — pásma drcení.
5. Přehledné geofyzikální schéma radiometrie.
   1 — anomálie bez geologického opodstatnění, *2* — anomálie odpovídající známým objektům, *3* — regionální anomálie vícekomponentní, *4* — regionální anomálie K, *5* — regionální anomálie U, *6* — regionální anomálie Th, *7* — regionální gradienty koncentrací — vícekomponentní, *8* — regionální gradienty K, *9* — regionální gradienty U, *10* — regionální gradienty Th, *11* — lokální anomálie vícekomponentní, *12* — lokální anomálie K, *13* — lokální anomálie U, *14* — lokální anomálie Th, *15* — regionální anomálie nízkého poměru Th/U, *16* — lokální anomálie nízkého poměru Th/U. Šrafováno vždy na straně vyšší koncentrace.
6. Přehledné geofyzikální schéma magnetometrie a gravimetrie.
   1 — anomální magnetické zóny — $\Delta T < 200$ nT, *2* — anomální magnetické zóny — $\Delta T > 200$ nT, *3* — vymezení jednotlivých magnetických zón, *4* — interpretované tektonické linie, *5* — izolinie tíhového pole, *6* — osy záporných tíhových anomálií, *7* — osy kladných tíhových anomálií, *8* — hranice aerogeofyzikálního mapování 1 : 25 000.

АЭРОГЕОФИЗИЧЕСКИЕ ИЗМЕРЕНИЯ В Ю.-З. ЧЕХИИ (ШУМАВСКАЯ ОБЛАСТЬ) И ИХ ИНТЕРПРЕТАЦИЯ

В баррандиенском протерозое в исследуемой области было обнаружено, что главным источником четких зональных магнитных аномалий является пирротин, присутствующий в продуктах палеобазальтового вулканизма, которые по данным радиометрии однозначно проявляются минимумом K, U и Th.

Область Среднечешского плутона по данным магнитометрии не проявляется. В поле концентраций радиоактивных элементов отчетливо наблюдаются с.-з. контакты частичных апофиз. В метаморфизованных островах плутона выступают крупные магнитные аномалии, обусловленные продуктами кислого и основного вулканизма, содержащими магнетит. Радиометрические аномалии свидетельствуют о значительной изменчивости пород островной зоны.

Область Молданубикума характеризована региональными аномальными зонами намагниченности преимущественно с.-в.—ю.-з. направления, источники которых представляют метаморфизованные вулканиты контрастного химизма, содержащие магнетит. Аномалии радиоактивности в в.-з. направлении могут наблюдаться длиной до десятков км. Они сопровождают жильные системы порфиров и порфиритов.

Přeložila H. Kuksová