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GEOMAGNETIC INVESTIGATIONS IN THE AUSTRIAN–HUNGARIAN BORDER ZONE: THE KŐSZEG–RECHNITZ MTS. AREA

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From 1985 to 1988 a geomagnetic survey (total field and vertical component) was carried out along the border between Austria and Hungary by a combined team from the Eötvös Loránd Geophysical Institute of Hungary and the Institute of Geophysics of the Mining University, Leoben. In this paper the results of the geomagnetic survey of the Austrian topographic map-sheet 138 (Rechnitz), are reported. Comparison of the results — presented in isoanomaly maps — with the distribution of susceptibilities shows that Penninic serpentinites with locally occurring metagabbro, ophicalcite and blue schist are the characteristic magnetic rocks of the investigated region. Therefore the geomagnetic anomaly pattern can be interpreted qualitatively as an indicator of the distribution of the Penninic ophiolite complex in the eastern part of the Kőszeg–Rechnitz Mts.

Keywords: Austria, Hungary, Penninic, Rechnitz window, geomagnetic survey, magnetic susceptibility

1. Introduction

If one studies the geomagnetic maps of the border area between Austria and Hungary, e.g. the ΔZ map of Hungary 1 : 500,000 [HAÁZ–KOMÁROMY 1966] or the aeromagnetic ΔT map of the Styrian basin — South Burgenland Rise, 1 : 200,000 [SEIBERL 1989] — it appears that in the area of the Kőszeg–Rechnitz Mts. there are significant anomalies on both sides of the border. Moreover, the helicopter-borne aeromagnetic measurements organized by the Geologische Bundesanstalt in 1983/84 [SEIBERL et al. 1986] also found anomalies in the Rechnitz area: the continuation of these anomalies is assumed to be in Hungary.

For the above reasons at a meeting of geophysicists from Austria and Hungary, an interest in joining and completing the geomagnetic maps was declared. In particular, a detailed ΔT and ΔZ survey along the border area was suggested. The necessary measurements were performed between 1985 and 1988 by a combined field group of the Eötvös Loránd Geophysical Institute of Hungary and of the Institute of Geophysics, Mining University, Leoben.

The project had basically two main parts: (i) a detailed ΔT and ΔZ survey of the Austrian map sheet 138, Rechnitz covering two-thirds Austrian, one-third Hungarian territory; (ii) and the establishment of a regional geomagnetic base network for the whole of the common border section. It is intended that the results of the second part be submitted for publication at a later date.

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In 1984 the Austrian party — as the first step of planning the detailed survey — collected all available geomagnetic data for South-Burgenland — mainly measurements of the vertical component — and checked, completed and transformed them into a standardized reference system. The next step was to estimate the costs and then to come to an agreement on the division of the tasks: on the basis of this, the Hungarian party were required to perform the ΔT measurements, the Austrian party the ΔZ survey.

The location map of the study area showing general topographic and geologic surroundings is shown in *Fig. 1.* As can be seen, the ΔZ map covers the whole mapsheet, while the ΔT map — as a direct continuation of the helicopter-borne aeromagnetic survey to the east — covers only the direct border area, i.e. the Hungarian part of the Kőszeg–Rechnitz Mts. Altogether there are 1650 ΔZ points and 700 ΔT points available. The average station density is 3 points/km^2 for both the 540 and 240 km^2 survey areas *(Fig. 2).*

2. Geological and petrophysical overview

According to PAHR [1980], and FÜLÖP–DANK [1987] the Kőszeg–Rechnitz Mts. are mainly built up of epizonal metamorphic crystalline schists (calc-, quartz-, graphite phyllites, calc-serizite schists and quartzite) with interbedded metamorphic ophiolites (greenschists, chlorite phyllite, serpentinite, metagabbro). As the Kőszeg–Rechnitz Mts. lie along the border, the geological prospecting was carried out by Hungarian as well as by Austrian geologists.

The rocks called 'Rechnitz series' by WIESENEDER [1932], according to their composition [SCHMIDT 1950], tectonic [PAHR 1960] and stratigraphic position [SCHÖNLAUB 1973] belong to the Penninicum. Therefore PAHR [1980] gave these rocks the name 'Rechnitz Penninnicum'.

As one can see from the geological sketch of Fig. 1. the Rechnitz Penninicum is overlain by the Lower East-Alpine Wechsel and Grobgneiss units and surrounded on all sides by young Tertiary sediments. The geomagnetic survey presented in this paper covers the eastern part of the Kőszeg–Rechnitz Mts. and large parts of the Tertiary surroundings, while the helicopter-borne aeromagnetic survey covers the western parts.

Within the framework of the International Geodynamics Project [WALACH 1977, WEBER et al. 1975, 1981] and later on in mineral exploration projects [WEBER and WALACH 1981, 1986–88], petrophysical studies were carried out on rock samples from the Nordostspron area in the Central Alps, from the Kőszeg–Rechnitz Mts. and the South-Burgenland Rise. Therefore the magnetic susceptibility distribution of the examined area is well-known. A comprehensive paper on palaeo- and rock-magnetic studies was published by MÁRTON et al. [1987].

The magnetic key rocks in the Kőszeg–Rechnitz Mts. *(Table I.)* are ophiolites, primarily serpentinites with a susceptibility of $35–160 \cdot 10^{-3}$ SI units.

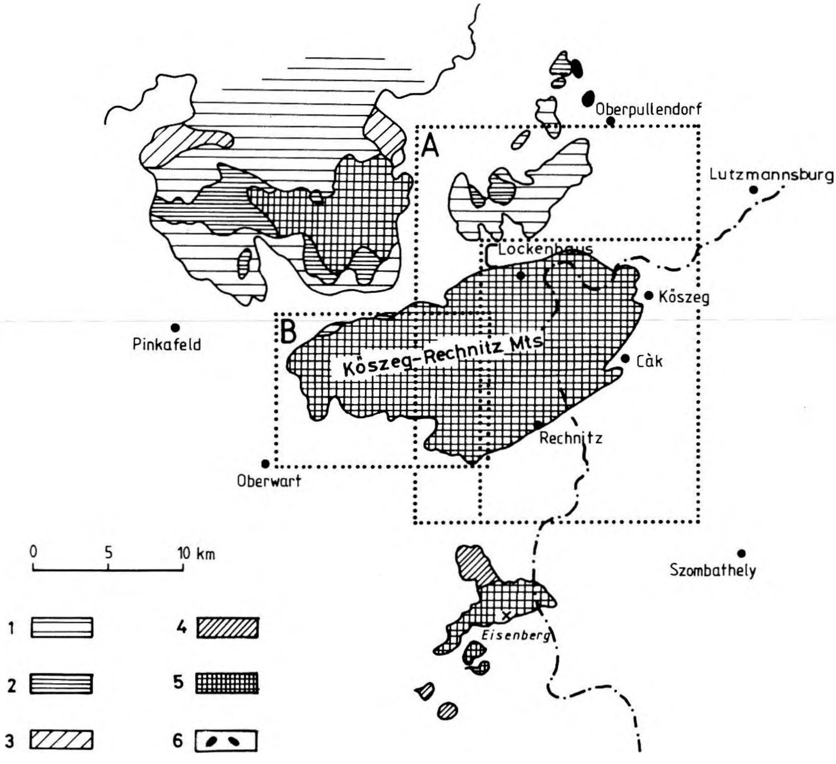


Fig. 1. Geological and geographical sketch of the survey area
1 — Grobgneiss unit (Lower East-Alpine); 2 — Wechsel unit (Lower East-Alpine); 3 — Crystalline (Middle East-Alpine); 4 — Palaeozoic (Upper East-Alpine); 5 — Rechnitz unit (Penninic); 6 — basalt (Pliocene); A — area of ΔZ ground mapping; B — area of helicopter-borne ΔT mapping; C — ΔT ground mapping

1. ábra. A kutatási terület földtani és földrajzi vázlata
1 — Grobgneisz egység (alsó kelet-alpi); 2 — Wechsel egység (alsó kelet-alpi); 3 — kristályos (középső kelet-alpi); 4 — paleozoos (felső kelet-alpi); 5 — rohonci egység (Pennini); 6 — bazalt (Pliocén); A — földi ΔZ-térképezés; B — helikopteres légi ΔT-térképezés; C — földi ΔT-térképezés

Рис. 1. Геолого–географическая схема района работ
1 — покров грубых гнейсов (нижне-австроальпийский); 2 — Вехсельский покров (верхне-австроальпийский); 3 — кристаллические комплексы (средне-австроальпийские); 4 — палеозой (верхне-австроальпийский); 5 — Рехницский покров (пеннинский); 6 — базальты (плиоцен); A — наземная съемка ΔZ; B — аэромагнитная съемка ΔT с вертолета; C — наземная съемка ΔT

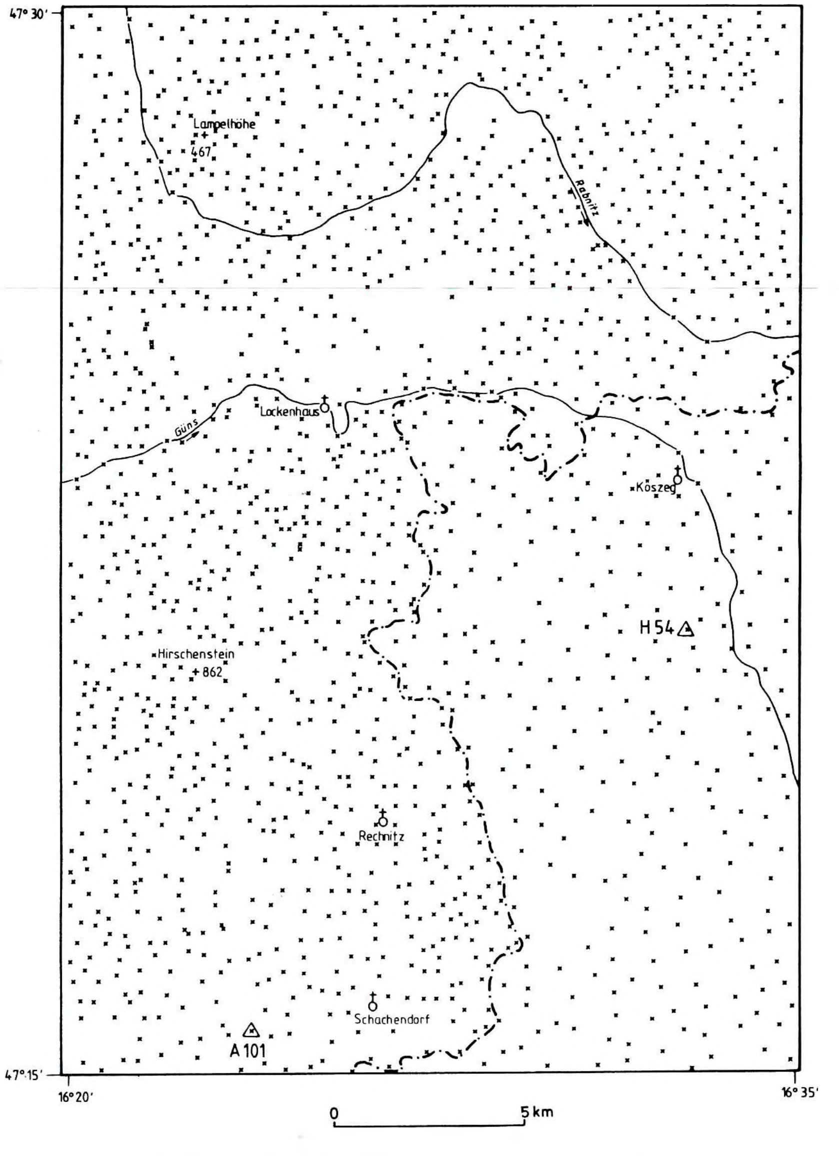


Fig. 2. Location map of the geomagnetic survey (Rechnitz)
A101 — 1st order basepoint Dürnbach; H54 — 1st order basepoint Kőszegdoroszló

2. ábra. A földmágneses mérések helyszínrajza
A101 — I. rendű alappont, Dürnbach; H54 — I. rendű alappont, Kőszegdoroszló

Рис. 2. План ситуации измерений магниторазведки A101 — опорный пункт 1-го класса, Дюрнбах; H54 — опорный пункт 1-го класса, Кёсегдоросло

Geological unit	Rock Type	Bulk density ($kg \cdot m^{-3}$)	Magnetic susceptibility (10^{-3} SI-unit)
RECHNITZ (Penninikum)	sericite phyllite	2670	1.0
	quartz phyllite	2660	0.1
	carbonate phyllite	2700	0.2
	marble (partly foliated)	2720	0.1
	conglomerate (Cák)	2750	0.1
	greenschist	2960	0.7
	ophicalcite	2780	5.0
	blueschist	2850	5.0
	metagabbro (a)	2980	30
	metagabbro (b)		0.8
	serpentinite (Fe_3O_4-poor)	2610	36
	serpentinite (Fe_3O_4-rich)	2980	160
	"Edelserpentin"	2680	0.3
WECHSEL (L. East Alpine)	albitegneiss	2700	0.6
	albitechlorite schist	2730	0.8
	mica schist	2680	0.6
	amphibolite	2920	0.7
	greenschist	2870	50
GROBGNEISS–COARSE GNEISS (L. East Alpine)	aplite gneiss	2620	0.3
	granite gneiss	2680	0.3
	mica schist	2700	0.2
	metagabbro	2950	0.6
	biotite schist	2860	0.6
	pegmatite	2650	0.1
PERMOMESOZOIC	quartzite	2660	0.1
	carbonate	2720	0.1
SIEGGRABNER S. (M. East Alpine)	paragneiss	2630	0.3
	serpentinite	2530	32
	amphibolite	2880	24
	eclogite	3360	2
HANNERSDORF –EISENBERG (U. East Alpine)	dolomite	2760	0.1
	"Rauhwacke"	2280	0.1
	shale	2680	0.6
	greenschist (a)	2860	0.6
	greenschist (b)		35
Young Tertiary volcanics		—	12–40
Quarternary and young Tertiary sediments		—	0.1–1

Table I. Bulk density and magnetic susceptibility of the most important rocks in the eastern margin of the Alps and the South-Burgenland Rise (WEBER et al. 1981, with additions)

I. Táblázat. A Keleti Alpok és a dél-burgenlandi küszöb legfontosabb kőzetfajtáinak térfogatsúlya és mágneses szuszceptibilitása (WEBER et al. 1981, kiegészítéssel)

Таблица I. Обёмный вес и магнитная восприимчивость важнейших порог Южных Альп и Южно Бургенландского порога (WEBER et al. 1981, с добовлениями)

Further locally occurring key rocks are ophicalcite, blue schists and some metagabbros with susceptibilities of $5–30 \cdot 10^{-3}$ SI. Detailed petrological and geochemical investigations were carried out on these Penninic rocks by KOLLER [1985] and by KISHÁZI and IVANCSICS [1986], respectively. Although slightly beyond the survey area the Upper East-Alpine greenschists of Hannersdorf ($35 \cdot 10^{-3}$ SI) as well as the young Tertiary volcanites ($12–40 \cdot 10^{-3}$ SI) of the Stool–Oberpullendorf area and of Pauliberg [SEIBERL 1978] should also be mentioned.

The susceptibilities of the Quaternary and Tertiary sediments are very low according to the numerous in situ and laboratory measurements: from $0.1 \cdot 10^{-3}$ SI (young Tertiary sand, Sinnersdorf Conglomerate) to $1.0 \cdot 10^{-3}$ SI (Quaternary loam). Therefore, neither they nor the carbonate- and quartz schists ($\kappa = 0.1–1.0 \cdot 10^{-3}$ SI) have any significance in the interpretation of magnetic maps. A special case is the area of the small streams coming from the serpentinites on the south flank of the Kőszeg–Rechnitz Mts. Their small sediment load may cause local anomalies because of the parent rocks some of which are highly magnetized. For example west of Rechnitz (Zuberbach) $\kappa = 5 \cdot 10^{-3}$ SI susceptibilities were measured on stream sediments. Therefore, in the survey the measurement points were located far from any rivers.

3. Measurement and interpretation methodology

The survey of the Hungarian part of map sheet 138, including the common frontier zone, was prepared in 1985 and executed in 1986. The magnetometer measurements were carried out by repeated readings and observations that were repeated three-five times daily at one of the basepoints. The co-ordinates of the survey points were read from topographic maps: 1 : 25,000 for Austria, and 1 : 10,000 for Hungary. Random checks at fixed geodetic points proved there to be no greater error than ± 20 m in the local positioning. This corresponds to an error of ± 0.15 nT in the normal field correction and can be neglected.

The ΔT measurements were carried out by a proton-precession magnetometer (GeoMetrics G 816) with a reading accuracy of 1 nT, while the ΔZ measurements by torsion magnetometers (ASKANIA GfZ and GfZ–M) with a reading accuracy of about 3 and 1 nT respectively. The second type of instruments (i.e. the torsion magnetometers) is based on the mechanical balance principle, and has already been used for 50 years. Therefore at the beginning of the program the drift and the calibration of the instruments [WALACH 1986] were checked, and for observations a mean square error of ± 5 nT was obtained.

To calculate the ΔT and ΔZ anomalies the values of the Hungarian normal field (epoch 1980.0) were taken into account by the following equations:

$$\Delta T = T - T_o \pm \delta T(t) \qquad (1)$$

and

$$\Delta Z = Z' - Z'_B \pm \delta Z_o \pm \delta Z(t) \qquad (2)$$

where

T = measured absolute value at the observation point
T_o = normal value at the point
Z' = measured relative value at the observation point
Z'_B = relative value at the basepoint
δZ_o = normal field correction
$\delta T(t)$, $\delta Z(t)$ = correction for daily variation

In compiling the ΔZ map, the problem of time variations arose; some of the data originated from as long ago as 10 years during which time the value of the vertical component changed by about +300 nT. It is pointed out, however, that in ΔZ anomaly map compilation, the absolute values are not very important. What is more important is the effect of the areal variation of the secular variation of the geomagnetic field. This was checked by repeated measurements on the basepoints A100 (Strem) and A101 (Dürnbach): For the epoch 1970.0 PÜHRINGER et al. [1975] obtained a difference between the two points of

$$\delta Z/(\text{Strem–Dürnbach})\ (1970.0) = 42.037 - 42.138 = -101 \text{ nT}$$

and, based on a repeat measurement in 1985, for the epoch 1980.0, approximately

$$\delta Z/(\text{Strem–Dürnbach})\ (1980.0) = 42.309 - 42.413 = -104 \text{ nT}$$

was obtained. This change of 3 nT is in the range of the observation error of the equipment utilized. Regarding the separation of the two base stations in the N–S direction (about 26 km), the 3 nT means a 0.12 nT/km N–S gradient difference in the normal field between 1970.0 and 1980.0. which is practically negligible, especially if the N–S extent of the survey area is less than 30 km. It was therefore concluded that the 1970 values are still valid, at least approximately, for 1980 as well. In view of this for anomaly calculations according to Eq. (2) — the normal field partial gradients defined by PÜHRINGER et al. [1975] were applied

$$\delta Z/\delta\varphi = 5.13 \text{ nT/km}, \qquad \delta Z/\delta\lambda = 0.80 \text{ nT/km}$$

To test this assumption, 16 stations along the Austrian–Hungarian border originally measured in 1977–79 were reobserved in 1985. Their location was unambiguously recoverable. Comparison of the ΔZ values led to a mean difference of ±5.2 nT, without any systematic error — e.g. a N–S trend. So — within the given limits of measurements error — a homogeneous data set was assured.

The reference anomaly values for basepoints A101 (Dürnbach) = +161 nT and H54 (Kőszegdoroszló) = +270 nT necessary for Eq. (2) were defined by connecting the base network in 1985 [WALACH 1986], and fitting them to the Hungarian national geomagnetic repeat survey of 1980.0. In order to record the daily variations the Hungarian party set up a mobile registration station (total field) in the survey area for the whole duration of the field work. For final calculations the T and Z registrations of the magnetic observatories of Tihany, Nagycenk and Vienna were used.

For map construction the anomaly values were interpolated by the Krieging method to a Gauss–Krüger net of 750 m grid interval thereby suppressing the anomalies of wavelengths smaller than 1.5 km. Taking into account the maximum horizontal gradient of more than 300 nT/km (Kőszeg area) and the map scale, a contour interval of 25 nT was chosen. The anomaly maps were computed and plotted by the graphic software UNIRAS in the computer centre of the Forschungsgesellschaft Joanneum in Leoben. The digital processing was carried out by R. Mayer and E. Posch.

4. Geomagnetic isoanomaly maps

The part of the South-Burgenland Rise between the Kőszeg–Rechnitz Mts. in the north and the lowland of Weixelbaum (Jennesdorf–Szentgotthárd) in the south constituting the Austrian–Hungarian border area is regionally a large magnetic high zone. As a simple sketch of the anomalous area *(Fig. 3.)* shows, a generally NNE directed anomaly main axis — although several times interrupted, a little bit shifted and situated in the area of the east flank of the South-Burgenland Rise — can be followed for about 80 km. In Austrian territory the anomaly zone was geologically thoroughly documented by outcrops and borehole data in order to be able to find a connection with the distribution of the Penninic serpentinites. Model calculations by OBERLADSTÄTTER et al. [1979] explain the regional anomaly by magnetized near-vertical dykes deeply penetrating the crust. Probably there is a relationship with the Penninic Ophiolite complex that has been described geologically and petrographically several times.

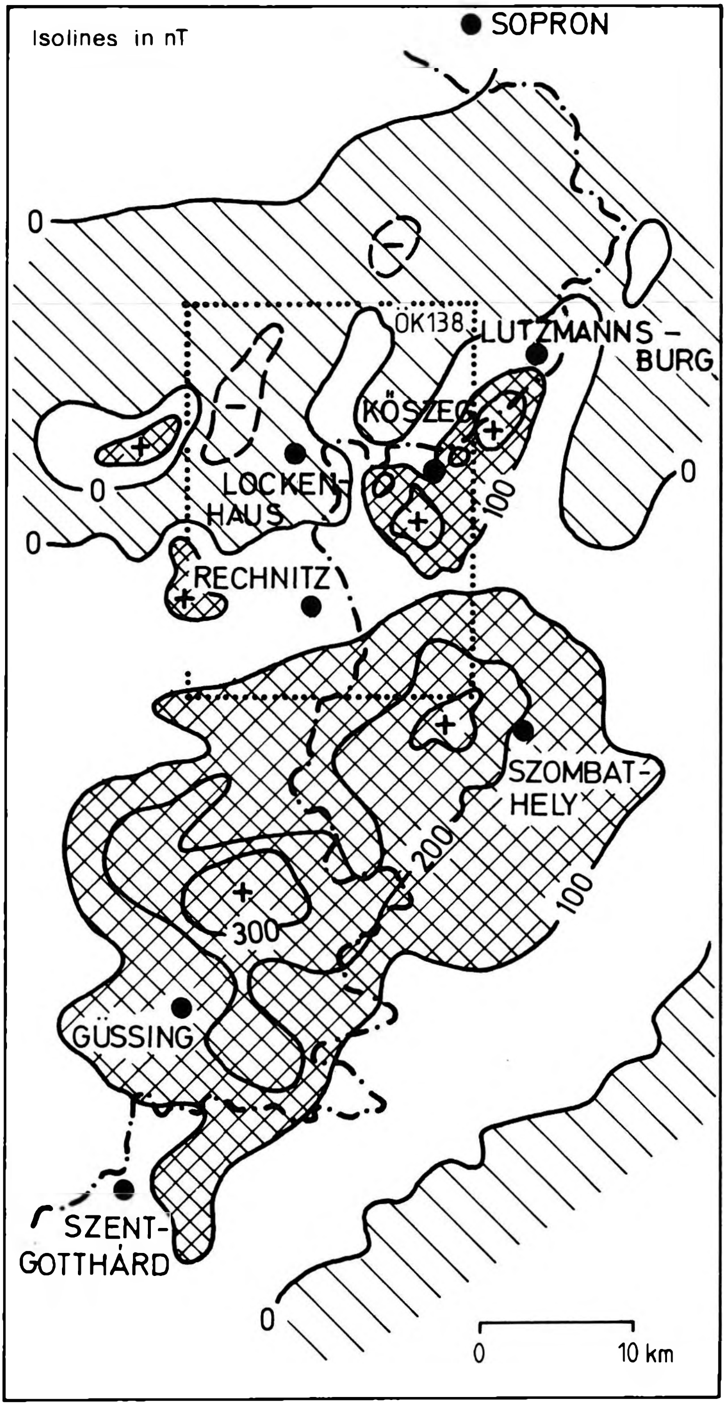
The prospected area, Austrian map sheet 138, lies on the northern flank of the described anomaly zone. A brief glance at the isoanomaly maps of *Figs. 3, 4* and 5 shows that the main anomaly between Güssing and Szombathely extends to the south of Rechnitz. Further to the north the maps show a more complicated anomaly pattern.

The Kőszeg–Rechnitz Mts. are crossed by two, almost parallel NNW directed, remarkable anomaly zones: one at Kőszeg and another on the western edge of the map sheet, west of Hirschenstein (Figs. 3 and 4). The western one (main part outside of the maps, see SEIBERL 1989) is regarded by PAHR [1980, p. 323) — in connection with ophiolite outcrops indicating high-pressure low-temperature paragenesis — as part of a subduction zone possibly tectonically dislocated by younger shear movements. By virtue of the similar anomaly pattern this interpretation can also be accepted for the anomaly in the Kőszeg area.

Fig. 3. Sketch of the geomagnetic anomaly field in the Austrian–Hungarian border area (old reconnaissance survey). Dotted frame: map sheet 138

3. ábra. Földmágneses anomália térkép az osztrák–magyar határ területéről (régi áttekintő felmérés). Pontozott keret: a 138-as térképlap

Рис. 3. Карта магнитных аномалий по окрестностям австрийско-венгерской границы (старая обзорная съемка). Пунктирная рамка — контур листа 138


Isolines in nT
SOPRON
ÖK138
LUTZMANNS-
BURG
KÖSZEG
LOCKEN-
HAUS
RECHNITZ
SZOMBAT-
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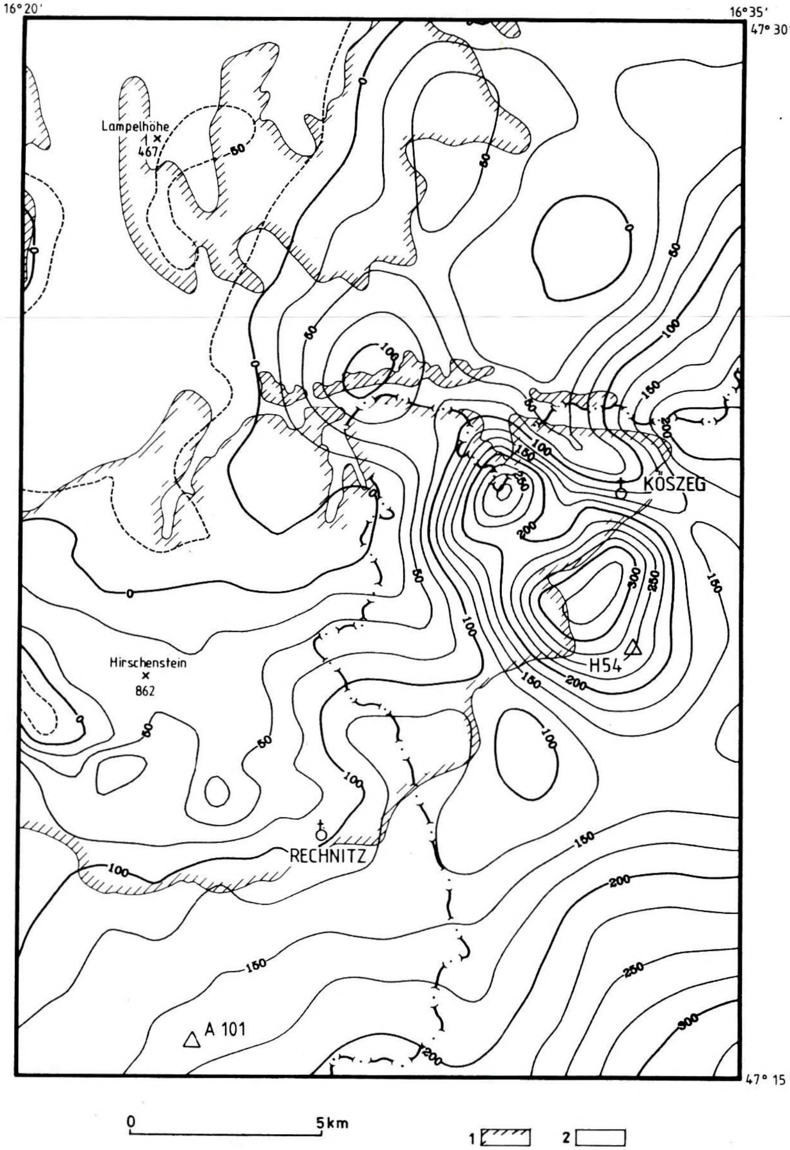

Fig. 4. Isoanomaly map of the vertical magnetic intensity, map sheet 138.
1 — basement outcrop; 2 — young sediments on the surface. Normal field: $\delta Z/\delta\varphi = 5.13$ nT/km; $\delta Z/\delta\lambda = 0.8$ nT/km. Basepoint values: A101 (Dürnbach): $Z_{1980.0} = 42{,}413$ nT, $\delta Z = +161$ nT; H54 (Kőszegdoroszló): $Z_{1980.0} = 42{,}585$, $\delta Z = +270$ nT

4. ábra. A vertikális mágneses tér (ΔZ) izoanomália térképe, a 138-as térképlap területén
Normál tér: $\delta Z/\delta\varphi = 5{,}13$ nT/km; $\delta Z/\delta\lambda = 0{,}8$ nT/km. Alappont értékek: A101 (Dürnbach): $Z_{1980.0} = 42.413$ nT, $\delta Z = +161$ nT; H54 (Kőszegdoroszló): $Z_{1980.0} = 42.585$ nT, $\delta Z = +270$ nT. 1 — alaphegység-kibúvás; 2 — fiatal üledékek a felszínen

Рис. 4. Карта аномалий вертикальной компоненты магнитного ноля (ΔZ) по листу 138.
Нормальное поле: $\delta Z/\delta\varphi = 5{,}13$ нт/км, $\delta Z/\delta\lambda = 0{,}8$ нт/км. Значения в опорных пунктах: A101 (Дюрнбах): $Z_{1980.0} = 42{,}413$ нт, $\delta Z = +161$ нт; H54 (Кёсегдоросло): $Z_{1980.0} = 42{,}585$ нт, $\delta Z = +270$ нт
1 — выходы пород фундамента; 2 — молодые отложения на поверхности

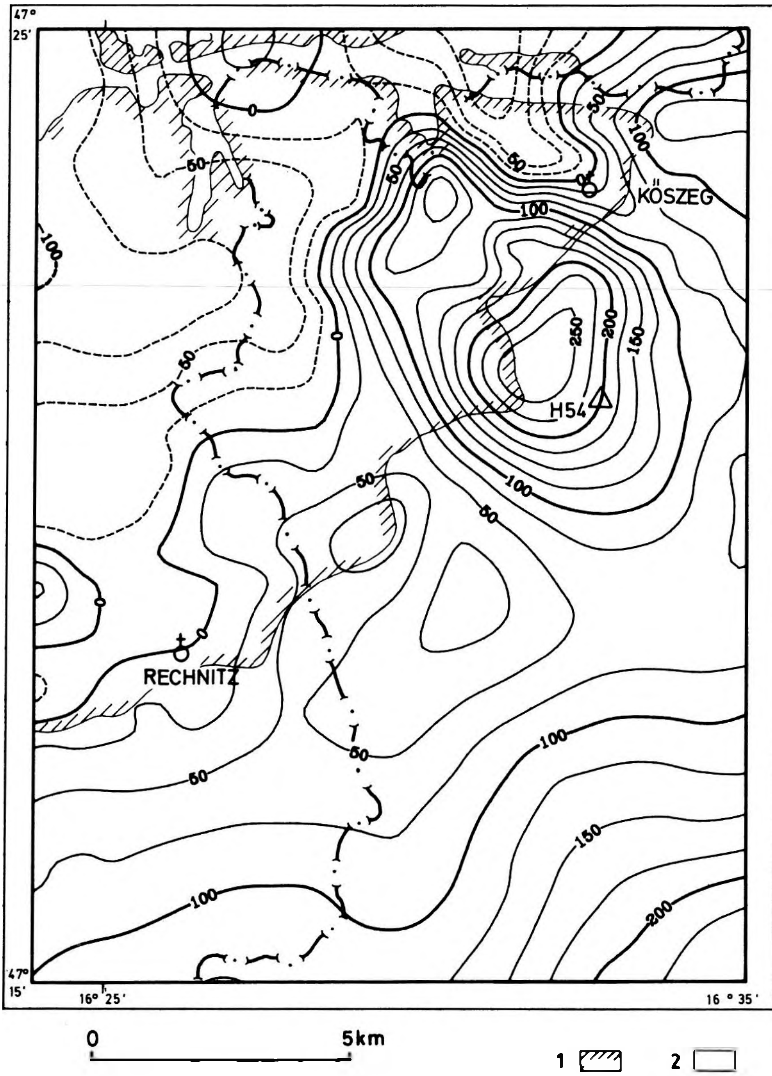

Fig. 5. Isoanomaly map of the geomagnetic total field, area of frame C in Fig. 1. Normal field: $\delta T/\delta\varphi$ = 2.51 nT/km, $\delta T/\delta\lambda$ = 0.75 nT/km. Basepoint values: H54 (Kőszegdoroszló): $T_{1980.0}$ = 47,581 nT, ΔT = +208 nT
1 — basement outcrop; 2 — young sediments on the surface

5. ábra. A totális mágneses tér (ΔT) izoanomália térképe az 1. ábrán C-vel jelzett területen. Normál tér: $\delta T/\delta\varphi$ = 2,51 nT/km, $\delta T/\delta\lambda$ = 0,75 nT/km. Alappont értékek: H54 (Kőszegdoroszló): $T_{1980.0}$ = 47.581 nT, δT = +208 nT. 1 — alaphegység-kibúvás; 2 — fiatal üledékek a felszínen

Рис. 5. Карта аномалий полного магнитного поля (ΔT) по району, обозначенному 'C' на рис. 1. Нормальное поле: $\delta T/\delta\varphi$ = 2,51 нт/км, $\delta T/\delta\lambda$ = 0,75 нт/км. Значения в опорных пунктах: H54 (Кёсегдоросло): $T_{1980.0}$ = 47,581 нт, δT = +208 нт
1 — выходы пород фундамента; 2 — молодые отложения на поверхности

North of the Lockenhaus–Kőszeg line, morphologically marked by the valley of the Güns river, the above-described eastern anomaly zone divides into two branches. With some offset from the anomaly at Kőszeg the main branch extends to the area north-east of Lutzmannsburg, where it decays [see Weber and Walach 1981]. The western branch runs approximately parallel to the main branch reaching the area of Oberpullendorf. The significantly lower amplitude and the flattening of the anomaly flanks of this branch mean greater depth and a small shift of the northern part of the magnetized body towards the west along an ENE line where the river Güns breaks through, east of Lockenhaus. From the regional anomaly distribution of Fig. 3 it seems that a similar north shifted element (shear body?) of the large ophiolite complex appears in the south, too.

In the NE corner of both isoanomaly maps an extended minimum zone can be seen. This is interpreted as the northern border of the ophiolites. Due to the bipolarity of the magnetic field this minimum zone (Fig. 3) is the northern accompanying minimum of the total Penninic (highly magnetized) basement complex. On the edge of the vertical intensity map (Fig. 4) the anomaly zone of the serpentinite outcrop of the Bernstein area starts just SW of Lampelhöhe.

The local anomalies on the southern flank of the Kőszeg–Rechnitz Mts. near Rechnitz area connected with the smaller serpentinite outcrops (Grosse Plischa, Budiriegel) of this area [Pahr 1980].

5. Conclusion and Acknowledgement

The results of the bilateral geomagnetic survey carried out in the border zone of Austria and Hungary proved the absolute necessity of further cooperation in the field of geophysics in order to solve the problems of geology — since geology is not concerned with state borders.

The authors wish to express their gratitude to both countries, for having permitted, promoted and covered all expenses of the joint project.

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FÖLDMÁGNESES KUTATÁS AZ OSZTRÁK–MAGYAR HATÁRZÓNÁBAN A KŐSZEGI HEGYSÉG TERÜLETÉN

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1985-től 88-ig az Eötvös Loránd Geofizikai Intézet és a Leobeni Bányászati Egyetem közös terepi csoportja az osztrák–magyar határ mentén földmágneses (ΔT és ΔZ) méréseket végzett. Jelen cikkben a 138-as (Rohonc) osztrák topográfiai térképlap földmágneses térképeit és értelmezésüket ismertetjük. Az izoanomália térképeken bemutatott eredményeket összehasonlítva a szuszceptibilitás eloszlással azt találjuk, hogy a pennini szerpentinitek helyi metagabbró, ophikalcit és kékpala előfordulásokkal a mágneses hatók. Ezért a jellegzetes földmágneses anomáliakép kvalitatíve úgy értelmezhető, mint a pennini ofiolit komplex terjedésének indikátora a Kőszeg–Rohonci hegység keleti részén.

МАГНИТОРАЗВЕДКА В ЗОНЕ АВСТРИЙСКО-ВЕНГЕРСКОЙ ГРАНИЦЫ В КЁСЕГСКО-РЕХНИЦСКИХ ГОРАХ

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В 1985–1988 годы совместной полевой партией Венгерского Геофизического института им. Л. Этвеша и Леобенского Горного института вдоль австрийско-венгерской границы выполнялась магниторазведка с измерением ΔT и ΔZ. В настоящей статье представляюстя геомагнитные карты по листу 138 (Рехниц) австрийской номенклатуры и их интерпретация. Путем сопоставления результатов, сведенных на картах аномалий, с магнитной восприимчивостью горных пород можно найти, что магнитовозмущающими телами являются пеннинские серпентиниты с локальными проявлениями метагаббро, офикальцитов и голубых сланцев. Поэтому характерные магнитные аномалии в восточной части Кёсегско-Рехницских гор могут быть качественно интерпретированы как индикаторы распространения пеннинских офиолитов.