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Low-resistivity element in the Carpathians

An enigmatic geological element, characterized by its very low electric resistivity, occurs along the arc of the Carpathians at depth of ca. 20 km, from the area Vienna to the area of the Marmarosh Mts. Among the various hypotheses regarding the nature of this body, the most probable is that of the presence of highly mineralized, hot waters saturating porous and fractured marine sediments of the flysch substratum. The sediments probably overlied an oceanic-type crust, that was later almost completely subducted at its contact with crusts of continental type. As a result of this process, the sediments saturated with solutions became drawn to depth, and their rapid covering by overthrusted Carpathian deposits prevented later squeezing of the water during compaction. The low-resistivity element is shown in relation to the results of geomagnetic and magnetotelluric soundings and of a gravimetric survey. The alignement of the anomalous body follows approximately the Picniny Klippen Belt, and a genetical link between the two is likely.

Geophysical methods consisting in study of propagation of natural electromagnetic waves (mainly resulting from solar activity, and partly the phenomena in upper layers of ionosphaere), reveal new information regarding the structure of the layers of the Earth. The methods of magnetotelluric and geomagnetic soundings applied here permit to trace variations of a geological cross-section to the depths of even several hundred kilometres.

The geomagnetic soundings with determination of the so called vectors of geomagnetic induction, initiated by H. Wiese (1965*a*, *b*), permitted to find occurrence of well-conducting rock-complexes at significant depths. H. Wiese (1965*a*, *b*, 1967) reports examples of such complexes from the North Germany and Western Czechoslovakia, at depths of 150 – 200 km. This was explained by presence of a current loop flowing at those depths in these regions. The geological explanation of this phenomenon was either not given of it was suggested that so high conductivity is due to the presence of partially melted metamorphic rocks (A.P. Bondarenko et al., 1972; I.I. Rokitjanski, 1975; W.B. Burjanov et al., 1978).

During his investigations on the Czechoslovak and Hungarian territory at late fifties H. Wiese (1965*a*, *b*) found a high-conductivity horizon at a depth more than ten and more than twenty kilometres beneath the Carpathians.

Similar investigations were carried out at the Polish territory by J. Jankowski (1967) at the middle of sixties, and these also revealed the presence of this element in the Polish Carpathians. J. Jankowski (*l.c.*) suggested that it is related to a sedimentary basin at the boundary of the East-European Platform and the Pannonian Plate, beneath the overthrust Carpathian orogene. Similar investigations were carried not much later in the Soviet Union (A.P. Bondarenko et al., 1972; I.I. Rokitjanski, 1975), also discovering a well conducting body in the eastern part of the Carpathians.

A team of scientists from the Institute of Geophysics of the Polish Academy of Sciences, led by J. Jankowski (1967) and from the Institute of Geophysics of the Czechoslovak Academy of Sciences, led by O. Praus (J. Jankowski et al., in press) realised, in 1973 – 1979, 90 geomagnetic soundings along 10 profiles, approximately transverse to the arc of the Carpathians. The measurements at each station lasted 3 – 6 weeks. They were aimed to obtain a full spectrum of variations with periods from 15 minutes to 2 – 3 hours. The results of these works permitted to trace the zone of the zero value of the induction vector with accuracy of few kilometres (according to the authors). This zone (in ideal conditions – line), according to the principles of the method used, determines the axis of the well-conducting rock-complexes. The values of the vectors on both sides of this zone are a function of conductivity, of depth of occurrence and of width of the discussed element. It allows, after accepting some assumptions, to interpret the geoelectric cross-section, also in the zone discussed here. South of this zone the vectors are directed southward, and north of it they are directed northward. The directions of the vectors are transversal to the generalized line of the Carpathians over the area of investigations discussed here. Taking into account also the results of the works of the Soviet geophysicists, the anomalous high-conductivity body is traced from the area of Vienna to the Marmarosh Massif, over a distance more than 700 km.

It should be also stressed that the absolute values of the induction vector registered in the Polish and Slovak Carpathians are among the greatest noted worldwide. It points to a unique nature of the element discussed here, with regard to its conductivity and size.

New data result from the magnetotelluric soundings realised by J. Święcicka-Pawliszyn and J. Pawliszyn with a team of the Enterprise of Geophysical Research (PBG). The soundings are ordered by the Geological Institute.

The first soundings were realised along the regional traverse F in 1975, and supplemented in 1978 – 1979 along the same traverse and along the V-th International Profile of the Deep Seismic Soundings. Since 1982 magnetotelluric soundings are realised in the Polish Carpathians at a large scale. The program of the Geological Institute includes making until 1990 a network of profiles perpendicular to the arc of the Carpathians (with possible supplements in other directions) by each 10 – 20 km. Measurements along each profile will be realised by each 3 – 5 km. It will be aimed to realize the measurements anywhere it would be possible, even in areas with medium level of disturbances, by use of special measurement techniques. Due to the high level of disturbances along the electrified railroad Katowice – Kraków – Przemyśl, it will be probably impossible to reach with the measurements to the very margin of the Carpathian overthrust. Nevertheless the area of the occurrence of the low-resistivity body would be studied satisfactorily.

The element under question is until now recognized over longest distance by geomagnetic soundings. So the first discussion below regards the path of the zone of the zero value of the geomagnetic induction vector. This zone is by most authors of papers on the subject referred to as "the zero-line of the induction anomaly".

This zone runs roughly in accordance with the Pieniny Klippen Belt, crossing it a few times (Fig. 1). Near the Austrian–Czechoslovak boundary (i.e. from where we can trace it) it lies ca. 20 km north of the Pieniny Klippen Belt, in the Outer Flysch Carpathians; further to the east it approaches the Pieniny Klippen Belt, and crosses it before the boundary between the Poland and Czechoslovakia. In Poland it runs first between the Pieniny and the Tatra Mts, closer to the latter, and further east the axis of the zone coincides with the Pieniny Klippen Belt. After having crossed again the boundary between the Poland and Czechoslovakia it again recedes outward of the Klippen Belt. Near the Czechoslovak–Soviet boundary and further to south-east both elements are distant by up to 30 km. So the low resistivity element is somewhat less convex than the Pieniny Klippen Belt and the Carpathian arc itself. It suggests that the processes which led to the arching of the Carpathians encountered a greater resistance in the case of the discussed element. It was less ductile than the flysch or was "protected" by more rigid elements.

The mathematic interpretation of the results of geomagnetic soundings requires some simplificating assumptions. J. Jankowski et al. (in press, and earlier works) assumed the anomalous body in form of a horizontally lying cylinder of infinite length. This assumption makes the interpretations simplest and in first approximation reflects the probable shape of the body, at least over the greatest part of its length. The interpretation indicates that the depth of this cylinder oscillates about 20 km. The report of J. Jankowski (*l.c.*) does not precises clearly if it is the depth of the cylinder axis, but it seems to be so. The occurrence is shallowest, from 16 to 18 km, west of the meridian 20°E to the north-eastern boundary of the Vienna Basin. Still further to west, close to the Austrian–Czechoslovak boundary, the depth rapidly increases to 24 km. Also in the east the depth increases, attaining 24 km at the V-th International Profile of the Deep Seismic Soundings, and south of the Dukla Pass it is determined as ca. 26.5 km. Further east, close to the boundary between the Czechoslovakia and the Soviet Union, the position of the cylinder axis becomes more shallow, attaining 21 km (data after J. Jankowski et al., in press).

Similar results, but in lesser extent, gives E. Ritter (1978) who cooperates with the Czechoslovak investigators, mainly in the western Bohemia. He relies mainly on the data received from the Czechoslovak geophysicists in his discussion of the area that interests us.

Due to the method of the geomagnetic soundings, widely dispersed in the field, more precise dimensions of the anomalous body could be not given. This deficiency should be overcomed by magnetotelluric soundings, performed at much greater density. They give, however, somewhat different results. A reservation must be made that the results given are tentative ones, according to the state at the end of August 1984 (J. Święcicka-Pawliszyn, 1984), but the definitive results should be not much different from those given here, and would only refine them. As all the materials in their complete form will be not known until after 1990, it seems warranty to present the current state of study by this method.

The very low registered longitudinal resistivity draws attention in the magnetotelluric results, it attains values of the order of 0.6 ohmm in profiles 1E and F (in

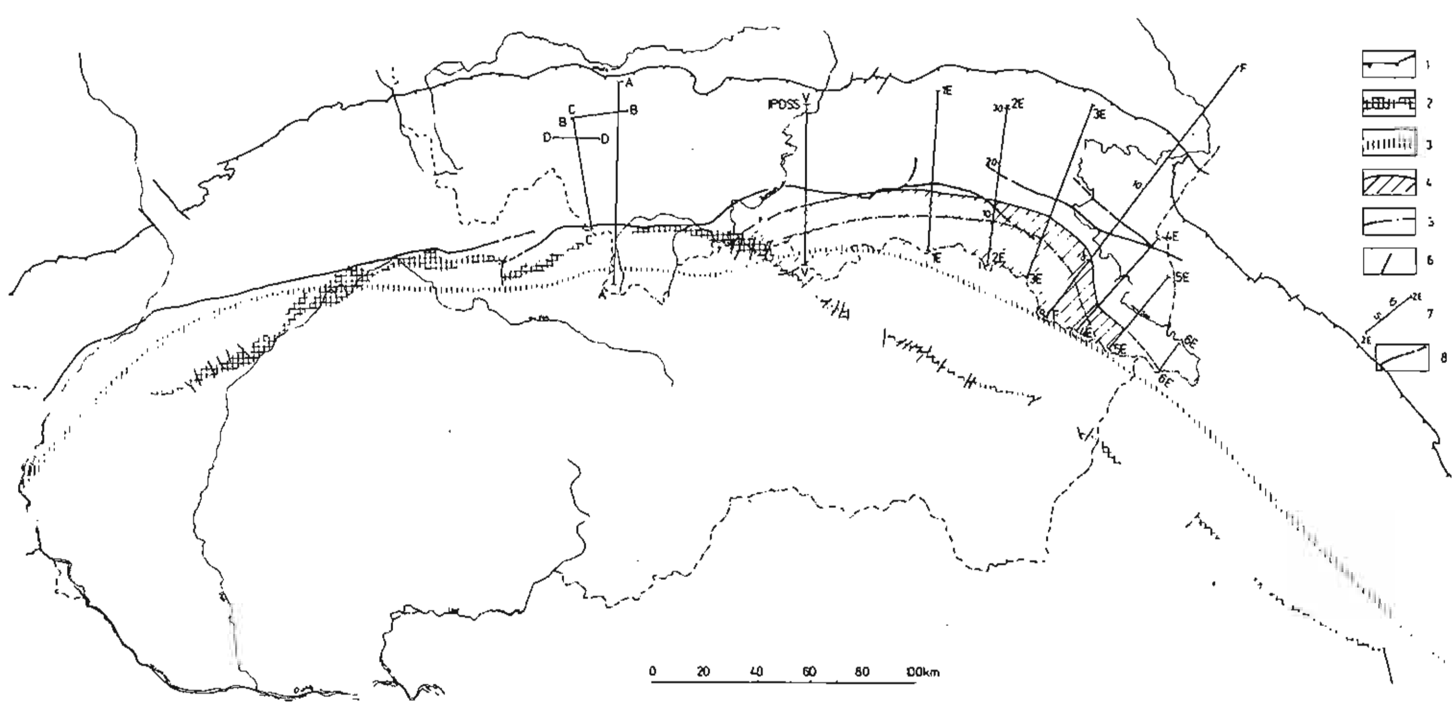


Fig. 1. Low-resistivity element in the Carpathians

Element niskoopornościowy w Karpatach

1 – outer margin of the Carpathian overthrust (according to M. Mahel, 1973); 2 – the Pieniny Klippen Belt (according to M. Mahel, 1973); 3 – zone of the zero value of the geomagnetic induction vector (according to J. Jankowski, in press); 4 – observed distribution of the low-resistivity element in the basement according to magnetotelluric data (according to J. Święcicka-Pawliszyn, 1984); 5 – "axis" of low-resistivity element; 6 – faults; 7 – magnetotelluric profiles; 8 – axis of gravity minimum

1 – brzeg nasunięcia karpackiego (według M. Mahela, 1973); 2 – pieniński pas skałkowy (według M. Mahela, 1973); 3 – strefa zerowych wartości wektora indukcji geomagnetycznej (według J. Jankowskiego, w druku); 4 – obserwowane rozprzestrzenienie elementu niskoopornościowego w podłożu według danych magnetotellurycznych J. Święcickiej-Pawliszyn (1984); 5 – „oś" elementu niskoopornościowego; 6 – uskoki; 7 – profile magnetotelluryczne; 8 – oś minimum grawimetrycznego

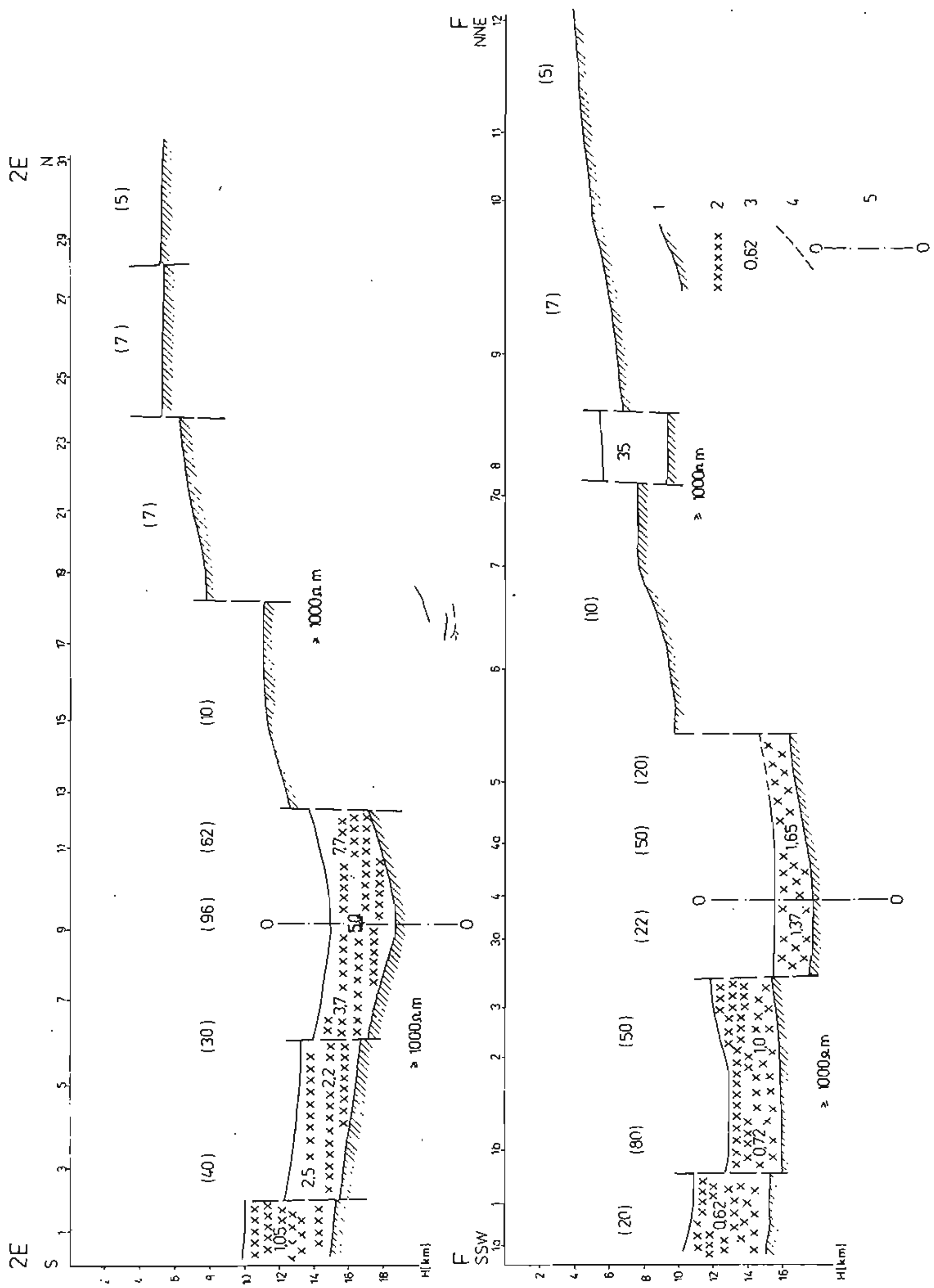
file data, in additional soundings off the profiles, there appear even values of 0.4 ohmm!). It is noteworthy that lower values of apparent resistivity occur on southern "limbs" of the anomalous body. Similarly, in the geomagnetic soundings, the vectors of induction to the south of the "zero zone" were greater than north of it.

If we accept the center of the deepest position of the bottom of the anomalous body as its axis (Fig. 2), a clear asymmetry becomes apparent in the geoelectric cross-sections. On south the body reaches closer to the surface (on profile IE – not included because of the tentative nature of its interpretation – to the depth of ca. 6 km) and has lower resistivity than on the northern side. At much lesser depth occurs there also the top of the underlying high-resistivity layer, most probably crystalline basement.

The geoelectric cross-section suggests that greatest thickness of sedimentary complex correspond to the axis the anomalous body (as defined above), as underlying layers display specific resistivity over 1000 ohmm and must belong to crystalline rocks. The lack of magnetotelluric data from the Slovak side precludes a fully documented conclusion, that also there (in area of the conductivity anomaly) the crystalline rocks remain at much shallower depths, and the sedimentary complex does not increase again in thickness. The known elements of the geological structure corroborate such a conclusion. It is in conflict, however, with the oppinion that the zone (line) of the zero value of the induction vector indicates the greatest thickness of the sedimentary basin.

At the actual precision of the magnetotelluric survey it seems that the low-resistivity body is running approximately according to the broad in that region gravimetric minimum, slightly to the south of its axis at least within the Polish territory. It should be stressed, however, that the discussed element can not be directly related with the gravity anomaly. The low-resistivity body is 2–6 km thick, occurs at depth interval 6–18 km (top according to magnetotelluric data), and width oscillates probably between 10 and 30 km, 40 at maximum. Detailed discussion regarding the nature of this body is presented below; it seems, however, improbable that its density be lower than that of the background by more than 100–200 kg/m^3 (0.1–0.2 g/cm^3). Simple calculation shows, that even at maximal values of the presented above parametres of the geoelectric cross-section, the values of the anomaly comparable to those registered in this area at the great Carpathian gravity minimum can be not obtained. It was noted already by M. Książkiewicz (1956) who estimated a realistic value of the gravimetric effect of sedimentary strata in the area of the Carpathian gravity minimum, as 20 milligals (200 nanoteslas in SI system), i.e. less than 20% of the anomaly. G. Bojdys et al. (1983) report that the greatest possible part of the Bouguer anomaly attributable to the effect of the sedimentary series equals a few, no more than twenty milligals, the maximum amplitude of the curve attaining 100 milligals. Taking into consideration similar position of the gravity minimum and the low-resistivity element it seems highly probable that both phenomena are due to the same geological process (or processes having a common cause).

G. Bojdys et al. (1983) during their gravimetric modelling along the profile Kraków–Zakopane used the model of W. Sikora et al. (1980), extrapolating it with the same assumptions to the depth of several tens of kilometres. Good fit of the model curve with the measured curve was obtained with acceptance of a geological model assuming the existence of a fracture zone displacing the Moho surface, resulting from the plate collision and the occurrence of the phenomenon of subduction at their convergence. The assumption of the subduction



process requires the existence of a contact of continental crust with oceanic crust; the presence of the latter in this part of the Carpathians during the formation of the orogene is denied by many geologists. It also not considered by J. Jankowski (1967) and J. Jankowski et al. (in press) who writes about the contact of two continental plates. Nevertheless, many geologists consider that the deposits of the Pieniny Klippen Belt were laid down on a oceanic – type crust (J.F. Dewey et al., 1973; D.P. Radulescu, M. Sandulescu, 1973; R. Ney, 1973, 1975, 1976; W.J. Sikora, 1973, 1976). According to this hypothesis the oceanic crust became almost completely subducted between the continental crust of the East-Europen Platform and the continental crust of the Panonian Plate. Considering the fact that in nearly all known cases of subduction the oceanic-type crust is consumed in more than 90%, the lack of convincing relics of the oceanic crust in the area of the Pieniny (until now) is not critical to the problem. The oppinion of M. Książkiewicz (1977) should be recalled here, who considered the evidence used by the above mentioned authors as uncertain and not verified, although, on the other hand he did not insist that the existence of subduction in this area is impossible.

W.J. Sikora (1973, 1976) rather decidedly supported the subduction theory, pointing to the phenomenon of andesitic volcanism registered along the Pieniny Klippen Belt, as an evidence supporting this thesis. Also the distribution of erthquake hypocentres in the Carpathians is related to the peri-Pieniny fracture zone and validates the subduction hypothesis (after W.J. Sikora).

According to W.J. Sikora (*l.c.*) the East-European Platform was underthrusting the Pannonian Plate, giving rise to deep-seated fracture zones and subduction of the cordilleras of the Carpathian sea together with a part of sedimentary strata of the Carpathian geosyncline.

The model of G. Bojdys et al. (1983) based on development of premises of W. Sikora et al. (1980) fits perfectly the known geological data, both along the Kraków – Zakopane profile and along the regional profile F (Baligród – Dubienka). At the former, some differences occurred only in the vicinity of the Pieniny Klippen Belt. The authors made a reservation that: "...the reasons for the other discrepancies can not be precised at the present stage of the modelling; they point to the divergence between the model and the real density distribution in the area". Indeed the results of the borehole Maruszyna IG 1 indicated that the assumptions of the geological cross-section by W. Sikora et al. (1980) were erraneous for this area. The modified cross-section, elaborated by K. Birkenmajer (1985), provides basis for a new geological-density model. This model significantly improves the fit between the results of gravimetric modelling with the measurements, also in the area of the Pieniny Klippen Belt.

As it was pointed above there exist discrepancies in determinations of parametres and position of the low-resistivity element discussed here. Much greater

Fig. 2. Simplified geoelectric cross-sections along the profiles F and 2E according to magnetotelluric soundings (according to J. Święcicka-Pawliszyn, 1984)

Uproszczone przekroje geoelektryczne wzdłuż profili F i 2E według sondowań magnetotellurycznych (według interpretacji J. Święcickiej-Pawliszyn, 1984)

1 – high-resistivity horizon; 2 – low-resistivity layer; 3 – values of specific resistivity (ohmm); 4 – faults; 5 – „axis" of low-resistivity element

1 – horyzont wysokoopornościowy; 2 – warstwa niskoopornościowa; 3 – wartości oporności właściwej w omometrach; 4 – uskoki; 5 – „oś" elementu niskoopornościowego

differences occur in the attempts to define the nature of this body. Some authors (W. Bachan, 1982) just write: "From the geophysical point of view the existence of this medium seems undisputable, its geological explanation, however, is at present impossible because of the lack of sufficient geophysical and geological recognition of this area". Despite of the pesimism expressed in this oppinion, let us try to formulate and support with an evidence a hypothesis with a high degree of probability, based on known facts from the fields of geology, geophysics and electrochemistry. We shall also present those earlier views which can be rejected, indicating the reasons for considering them unjustified.

The possibility of existence of currents loop flowing at significant depths, suggested by H. Wiese (1965*a*, *b*, 1967), influenced most authors, especially the Soviet ones. There was already mentioned above a model where the good conductor was represented by melted metamorphic rocks. Apart of the geophysicists mentioned above this model was accepted by W.B. Burjanov et al. (1978), and also initially by J. Jankowski et al. (1977). Two arguments contradict this hypothesis:

1. In geological history of the Carpathians, a significant additional heat flow occurred 40–45 m.y. BP (R.J. Kutas, W.W. Gordienko, 1972) and probably resulted in thermal-regional metamorphism of those sedimentary rocks of the Carpathian geosyncline which became drawn into deeper parts of the orogene (W.J. Sikora, 1976). The temperatures then occurring at the depth of occurrence of the low-resistivity element are estimated as up to 700 K (400°C), i.e. sufficient for low-temperature metamorphism. It is, however improbable, even impossible, the metamorphism of these rocks in these conditions, so that the segregation of the minerals with electron conductivity (native metals, metal sulphides, graphite) could occur.

2. The naturally occurring minerals with electron conductivity only rarely form concentrations resulting in low total specific resistivity of the rock. Moreover these rocks form bodies of small dimensions. It is theoretically possible, especially at very high pressures, that conductive minerals attain such arrangement, that the skin effect would occur, resulting in high electric conductivity of the whole complex. Perhaps such is the nature of the well conducting complexes at depths below 100 km. Nowhere in the world, however, the possibility was proved of the occurrence of such a phenomenon at depths of the order of twenty kilometres. With the ascertained parameters of the element discussed here, the occurrence of this unique phenomenon can be with full certaininity rejected.

A later hypothesis of J. Jankowski et al. (in press) is material and highly probable, i.e. that the anomaly is due to the presence of highly mineralized, thermal waters within porous sedimentary rocks. This hypothesis deserves wider extension, than it has been done by its authors, both on the geological as on the electrochemical part.

To simplify the reasoning the mineralization of the solutions by NaCl exclusively will be assumed; the presence of other electrolites does not affect, hower, the qualitative aspect of the phenomenon, and only slightly affects the quantitative aspect.

Specific resistivity of marine water with salinity ca. 30 g NaCl/dcm^3 is only 0.08 ohmm at temperature of 300 K and atmosphaeric pressure (*Sprawocznik gieofizika*, 1963). At the brine saturation of 100 g NaCl/dcm^3 it decreases to 0.03 ohmm. The temperature increases with depth, at medium value of geothermal gradient of 50 m/K, and can attain 600 K (300°C) at depth of 15 km. It gives, at the temperature coefficient 0.025 K^{-1}, 8.5-fold increase in condictivity! Thus we obtain the values of specific conductivity of the order of thousandths parts of ohmometre. If in such conditions would occur a rock with total porosity and fracturing (open) of several percent, we obtain an summary specific resistivity much below one ohmometre, as it is observed. This range of porosity occurs even in the granitoids encountered in the world's deepest borehole, at the Cola Peninsula, at depths above 10 km. There are no reasons, thus, why such porosities and fracturings could not occur in deep-sea deposits, relatively rapidly covered with flysch deposits sealing them. It should be stressed that frequent events are submarine lava flows, transformed into pumice with porosity surpassing 50%. The deposits of this kind, even under a greater thicknesses of rock masses than in our case, maintain porosities above 10%. It is not necessary to accept the hypothesis of occurrence of such pumices saturated with solutions, as the conductive element, to explain the observed parametres of the anomaly, and it is less probable than the occurrence of the deposits described above.

Another argument in favour ot the model of a sedimentary rock saturated with hot solutions in the distribution of the resistivity values within the body. The lowest values occur in those places, where the body occurs at shallowest depths, and near the axis (according to the definition given above) the values are ever higher. Taking into account that at shallower depth the temperature is lower, and ion mobility lower, the electric resistivity should be higher. This paradox can be explained if we take into account the compaction, which is in general the function of pressure, and at first approximation the function of depth. The same rocks, at greater depth, are more compacted and less porous, their humidity is thus lower, while the rock at higher position maintains more solution. At relatively low porosities this factor has a stronger effect, than the temperature rise, leading to the phenomenon observed.

It should be also noted, that the elevated temperature of the solutions, repeatedly mentioned above, is exelusively due to the geothermal gradient. The accepted value of 50 m/K corresponds to the mean value for the Flysch Carpathians; for most of the Europe (excluding the East-European Platform) higher values are assumed, of the order 30 – 35 m/K. There are no reasons to supose that an additional heat source is now active, rising the temperature of the waters above that observed (more precisely – calculated) at those depths at the Carpathians.

It seems that there is a relation between the distribution of the part of the mineral waters in the Carpathians and the low-resistivity element discussed here. It is possible that there exist routes of migration along tectonic lines, conducting mineral waters from the described body towards the surface. It would be, however, premature to try to document such a relation at the present state of recognition of the position of the low resistivity element. It will be presented at the close of the planned work.

It is worth reflection, before terminating, what is the age of the discussed element? Assuming that the analogy between the alignement of the Pieniny Klippen Belt and the low-resistivity element is not casual, we must assume that there was one process active, at one time. The oppinion of W.J. Sikora (1976) about the mainly Miocene age of the peri-Pieniny fracture zone formation (begining in Oligocene, terminating in Sarmatian-Pliocene) is probably also correct for the origin of the horizon under discussion.

CONCLUSIONS

1. It ascertained above any doubt that there occurs in the Carpathians, by at least two geophysical methods, that there occurs in the Carpathians a well conducting body at depth ranging from 6 to above 20 km.

2. Its position registered as a zone of zero value of geomagnetic induction vector follows approximately the position of the Pieniny Klippen Belt.

3. This body is recorded on the curves of magnetotelluric sounding, but its position is somewhat displaced (according to the data from the Polish territory), with regard to the data from the geomagnetic soundings. The displacement is towards the gravity minimum. With the present density of measurements, a correlation is perceptible between the position and shape of the gravity minimum and the low-resistivity element in the area of the Central Carpathian Depression, where the gravity minimum is relatively broad with some branchings of its axis, and some an echelon displacements of it, and the broadly extended anomalous body (after the magnetotelluric data) is similarly oriented. In profiles further to the west the body becomes distinctly narrower.

4. The explanation of the nature of this body as a complex of sedimentary rocks saturated with highly mineralized, hot water, may be considered as certain.

5. It seems that over a distance of several hundred kilometres the following elements are mutually correlated;

a – Pieniny Klippen Belt;

b – the zone of zero value of the geomagnetic induction vector;

c – the position of the low-resistivity body as shown by interpreted from magnetotelluric soundings;

d – Carpathian gravity minimum.

A hypothesis that all result from the same process is tempting. The process could be prolonged and complex. There are many arguments for the drawing to depth of the Carpathian cordilleras together with deep-sea sediments of the flysch troughs. The process could result from the subduction of the ocean-type crust at the contact with a continental-type crust. The process could occur at the contact of the East-European Platform with the oceanic crust – at north, and at the contact of the oceanic crust with the Pannonian Plate – at south. It could also occur at only one of these contacts, and then the former would be more probable. It is suggested by the "step-like" descondance of the basement beneath the Carpathians observed on the north side in seismic investigations, especially by the method of deep seismic soundings. According to the results of gravimetric modelling this process of basement sinking and drawing down of sedimentary rocks extends deeply into the lithosphaere.

Translated by G. Haczewski

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Ежи ВОЗНИЦКИ

ГЕОЛОГИЧЕСКИЙ ЭЛЕМЕНТ НИЗКОГО СОПРОТИВЛЕНИЯ В КАРПАТАХ

Резюме

Вдоль дуги Карпат от Вены до района Мармароши на глубине порядка 6—30 км тянется загадочный геологический элемент, отличающийся весьма низким удельным электрическим сопротивлением. Этот факт был установлен двумя методами: геомагнитным зондированием и магнитотеллурическим зондированием. Получаемые величины удельного сопротивления были порядка нескольких омометров, а в отдельных случаях ниже 1 омометра. Согласно геомагнитному зондированию, положение этого тела совпадает с положением Пенинской Утесовой зоны. По магнитотеллурическим данным, раскрывающим более широкую картину, это тело смещено несколько далее на север, в сторону гравиметрического минимума, причем это касается только территории Польши и данные получены по довольно редкой сетке. Для детального выяснения этого явления по заказу Геологического института будут в широком масштабе вестись магнитотеллурические исследования по крайней мере до 1990 года.

Что касается строения этого тела, то высказывались разные гипотезы. Наиболее вероятным следует признать присутствие в нем осадочных пород, пористость которых достигает нескольких процентов, насыщенных высокоминерализованными растворами и ввиду их глубокого залегания весьма горячими, температура которых близится к критической для вод.

Представляется вероятным, что на протяжении нескольких сотен километров коррелируются такие элементы как: Пенинская Утесовая зона, зона нулевых значений вектора геомагнитной индукции, протяженность этого тела с низким сопротивлением согласно интерпретации магнитотеллурического зондирования и карпатский гравиметритический минимум. Заманчивой является гипотеза, принимающая, что это результат одного и того же процесса. Он мог быть длительным и сложным. Сопоставляя все эти данные с уже известными фактами и геологическими гипотезами, а также с результатами и выводами, вытекающими из гравиметрического моделирования, снискано множество аргументов в пользу того, что здесь карпатские кордильеры были втянуты вместе с глубинными отложениями флишевых впадин. Происходило это, вероятно, главным образом в миоцене. Причиной могла послужить субдукця покрова океанического типа на контакте с покровом континентального типа. Этот процесс мог происходить на сочленении Восточно-Европейской платформы с покровом океанического типа на севере и на контакте океанического покрова с Паннонской плитой на юге. Процесс мог иметь место только на одном из этих контактов и тогда более вероятным был первый из них. В пользу такого явления говорит наблюдаемое сейсмикой, особенно глубоким сейсмическим зондированием, „ступенчатое" погружение фундамента под Карпатами. Согласно данным гравиметрического моделирования этот процесс погружения фундамента и втягивания осадочных пород простирается далеко вглубь литосферы.

Jerzy WOŹNICKI

NISKOOPORNOŚCIOWY ELEMENT W KARPATACH

Streszczenie

Wzdłuż łuku Karpat od rejonu Wiednia do rejonu Marmaroszy na głębokości rzędu 6–30 km występuje zagadkowy element geologiczny, charakteryzujący się bardzo niską elektryczną opornością właściwą. Stwierdzono to dwiema metodami: sondowaniami geomagnetycznymi i sondowaniami magnetotellurycznymi. Rejestrowane wartości oporności właściwych są rzędu kilku omometrów, a sporadycznie nawet poniżej 1 ohmm. Usytuowanie tego ciała według metody sondowań geomagnetycznych jest zbliżone do przebiegu pienińskiego pasa skałkowego. Według sondowań magnetotellurycznych, dających obszerniejszy obraz, jest ono przesunięte nieco dalej na północ, w stronę minimum grawimetrycznego, przy czym dane te mamy wyłącznie dla obszaru Polski i na razie w dość rzadkiej siatce. Dla dokładniejszego wyjaśnienia tego zjawiska badania magnetotelluryczne będą prowadzone na zlecenie Instytutu Geologicznego na szeroką skalę, co najmniej do 1990 r.

Co do charakteru tego ciała wysuwane są różne hipotezy. Za najbardziej prawdopodobne należy uznać przyjęcie obecności skał osadowych o porowatości rzędu kilku procent, nasyconych silnie zmineralizowanymi roztworami, mającymi – ze względu na głębokość zalegania – bardzo wysoką temperaturę, bliską temperatury krytycznej dla wody.

Wydaje się, że na kilkusetkilometrowym odcinku korelują się ze sobą takie elementy jak: pieniński pas skałkowy, strefa zerowej wartości wektora indukcji geomagnetycznej, przebieg ciała niskoopornościowego według interpretacji sondowań magnetotellurycznych i karpackie minimum grawimetryczne. Nęcąca jest hipoteza, że jest to wynik jednego procesu. Mógł on być długotrwały i skomplikowany. Zestawiając powyższe dane ze znanymi faktami i hipotezami geologicznymi oraz wynikami i wnioskami wypływającymi z modelowania grawimetrycznego, uzyskuje się wiele argumentów przemawiających za tym, że nastąpiło tu wciąganie kordylier karpackich wraz z głębokowodnymi osadami rowów fliszowych. Zjawisko to zachodziło prawdopodobnie głównie w miocenie. Przyczyną procesu mogła być subdukcja skorupy typu oceanicznego na kontakcie ze skorupą typu kontynentalnego. Na północy proces ten zachodził przypuszczalnie na styku platformy wschodnioeuropejskiej ze skorupą typu oceanicznego, na południu zaś na kontakcie skorupy oceanicznej z płytą pannońską. Mógł on też mieć miejsce tylko na jednym z tych kontaktów i wtedy prawdopodobniejszy był pierwszy z nich. Przemawia za tym obserwowane w badaniach sejsmicznych – zwłaszcza metodą głębokich sondowań sejsmicznych – „schodkowe" zapadanie się podłoża pod Karpatami od strony północnej. Według wyników modelowania grawimetrycznego proces zapadania się podłoża i wciągania skał osadowych biegnie daleko w głąb litosfery.