

# GEOLOGICAL AND PETROGRAPHICAL PRINCIPLES APPLIED IN RESEARCHES FOR RADIO-ACTIVE ELEMENTS IN HUNGARY.

BY A. FÖLDVÁRI

*Introduction.* Early in 1947 Prof. S. Szalay wanted to make radioactivity measurements on Hungarian igneous rocks. Specimens of the geological Institute's collection have been put at his disposal. As some of the Velence Mountain rocks showed higher radioactivity than the average, radiometric survey has been proposed in order to find any accumulation of uranium. T. Szalai, leader of the Geological Institute made a suggestion for these investigations which has been approved by the Mining Dept. of the Ministry of Industries. According to the plans a small expedition has been organized consisting of physicists, a chemist and a geologist. The geological leader was A. Földvári chief-geologist who was acquainted by his earlier surveys (molybdenum, alunite prospects) with the territory. Field work could not be finished according plans because the geologist became by infantile paralysis infection, unable to walk. The survey was followed by laboratory investigations, which shall be carried on. Our experiences and further plans are reported in the followings.

## Geological types of radio-active deposits.

A theoretical study of all possibilities of uranium accumulation formed the starting point in constructing the detailed plan of prospects. In the literature following types are recorded:

1. *Pegmatites.* At the solidification of granites uranium becomes accumulated in the gaseous magma residue because uranium cannot enter by its great ionic radius into the lattice of rock-forming silicates. Naturally uranium does not attain a high concentration in all pegmatites. Famous occurrences of this type are in Europe: the Portugese-Spanish borderland, Oslo distr. and the region of

Langesund fjord in Norway, North-Karelia, Bulgaria. In Africa: Uluguru Mountains in East-Africa and Madagascar. In Asia the Indian pegmatites, in America the Black Hills in South Dakota and Canada. Uranium-bearing pegmatites have been found even in Australia. General characteristic of this type of occurrences is their relatively small quantity though Canadian pegmatites furnished pitch-blende blocks of several tons. Pegmatitic uranium occurrences will be exploited probably in short time, they cannot be held for uranium sources of the future.

2. *Uranium with cassiterite formations.* These pneumatolytic occurrences appear on the margin of granitic masses forming impregnations or veins in the granite itself or in the contact metamorphic schists. Uranium is accompanied by tin, bismuth, cobalt, nickel, sulphidic copper ores, arsenopyrite, silver and zinc. Type localities: St. Ives, St. Austell, Grampound in Cornwall, Schlaggenwald in Bohemia.

The occurrence of Schmieberg (Riesengebirge) represents a different variety of above type, marked with 2a. In this contact pneumatolytic deposit uranium is accompanied by magnetite, hematite, sulphidic copper and silver ores. In this occurrence located next to a granite mass, cassiterite is absent.

3. *Uranium in hydrothermal lodes* (and their impregnated wallrocks). The deeper horizons of cobalt, nickel, silver, bismuth lodes are sometimes uranium-bearing characterized by reddish calcite and dark violet fluorspar. Famous occurrences: Jachymov (= Joachimstal) in Bohemia, Gilpin (Colorado, U. S. A.) accompanying silver, gold and bismuth ores; Luivishi, Shinkolobve in Katanga distr. (Belgian Congo) with sulphidic copper ores.

Occurrences of type 2., 2a., and 3. are grouped by P. Krusch under the name sulphidic uranium ores.

4. *Sedimentary uranium deposits.* Anorganic uranium accumulation can be found with some vanadium and copper ore deposits. E. g. in sandstones of Colorado (U. S. A.) and limestones of Tuja-Mujun (Turkestan, U. S. S. R.) Organic uranium accumulations can be separated under 4a. The «kolm» concretions of Cambrian coal seams of Sweden contain uranium in considerable quantity, which is concentrated in their ashes. Relying on the result of J. Stoklasa—J. Penkava (Biologie des Radiums und Uraniums, 1932) about the wide spread uranium content of plants in the crater of Kammerbühl, the «kolm» can be held for product of organic uranium concentration.

5. *Diffuse radio-active content of igneous rocks.* The diffused radioactivity is especially characteristic to granites and its acid schizolites. The pleochroic haloes appear around some small crystals, the radio-active elements seem to be concentrated in these minute particles. Formerly these particles were held for zircon. Recent investigations (C. Osborn Hutton: The nuclei of pleochroic haloes) revealed that they are monazite, xenotime, or apatite.

## Possibilities of uranium occurrence in the Velence Mountain.

According to our present geological knowledges only 2a. and 5. types of uranium accumulations can be suspected in this region. A pegmatite exposure discovered by present survey indicated some possibility of occurrence of type 1. Type 2. could not be suspected as cassiterite formation is entirely lacking in Hungary. Type 4. is not represented either. Permian sandstones of the Balaton region formed by denudation of Palaeozoic crystalline rocks were supposed to be analogous with the carnotite-bearing sandstones of Colorado, but they proved to be inactive. (Similar sandstones of Germany, though containing vanadium are also free of uranium.)

### Geological and petrographical constitution of the Velence Mountain with respect to radio-active occurrences.

According to A. Vendl's monography the Velence Mountain is formed by a  $40 \times 7$  km granite mass surrounded on the north, west and east by a contact metamorphic envelop. On the south of the mountain, on the shore of the Velence lake, this envelop is lacking due to a great dislocation, producing the assymetric structure of the mountain. On the central elevated part of the mountain the envelop of metamorphic schists has been denudated. On the east and west the granite mass has been thrown down by transversal faults but of much smaller scale than on the south. A shear-zone of these eastern faults has been exposed by the drilling of Velence in 1948. Granite porphyry, aplite, quartzite, kersantite dikes related with the granitic intrusion have a NE—SW strike. Tertiary andesites and hydro-quartzites genetically connected with them have a transversal strike of NW—SE. The formations of the envelop are exposed by the mining operations of Polgárdi—Falubattyán, the Velence and Székesfehérvár drillings. This includes contact metamorphosed limestones, phyllites, fossiliferous Carboniferous limestones, Carboniferous shales, porphyroide, Permian mottled shales, and a sandstone, probably dynamo-metamorphosed greywacke. Further details are given in the author's two other publications to which reference is made (6,7).

As far as rock-forming processes are concerned, attention is to be paid to A. Vendl's statement, that aplites derived from gas-rich magmas and that they have been formed under high pressure. Two pegmatite occurrences discovered in Retezi's quarry near Velence and in the quarry on the W of Pákozd indicate also the presence of a gas-rich magma. (The pegmatites consist of large euhedral quartz and orthoclase crystals including some cavities). These observations might indicate favourable conditions for the formation of pneumatolytic occurrences (type 1. and 2.). A further analogy can be established with other uranium occurrences related with quartz-

porphyry dikes by the fact, that the aplites have a porphyric structure and they might be called quartz-porphyry as well. The quartz-porphyry gravels wide spread in our Tertiary gravel beds might derive from the Velence Mountain or its eroded prolongation.

Radio-active measurements have been plotted according to a general scheme in order to solve all questions concerning the radio-activity of each rock variety, rock alteration and structural line. Granitic rocks have generally uniform activity, but more mafic types and ferric fissurefillings seem to have stronger radiation. The melanocratic kersantites however proved to have very low activity. Radiation of the pegmatites does not exceed the one of normal granites. A great part of contact metamorphosed schists has the same activity as granites which can be explained by material transport of metamorphism.

All the other rock varieties proved to be inactive excepted some quartzites of rich ferric impregnation. It is a well known fact, that radio-active compounds can be adsorbed by ferric oxide, we have to do therefore with a secondary enrichment from trickling waters.

Measuring data are given in the table (p. 45.), measuring points of some better exposed areas are shown on the sketch-maps. (fig. 1—4.)

### Mining possibilities.

At the weighing of the possibilities of a profitable uranium occurrence following factors are to be born in mind:

*Positive factors.* 1. The granite mass of Velence Mountain attains the size of the Cornwall granite, it represents therefore a ground mass great enough for a possible concentration. From three sides the granite mass is surrounded by a contact metamorphic envelop in which formation of ore deposits could take place. 2. The granite magma was rich in gaseous components. 3. Massy occurrence of dark violet fluorspar characteristic to uranium occurrences has been traced along a quartzite dike near Pátka. (Mining prospects made in 1948 exposed even traces of lead-copper-silver metallization.) 4. Molybdenum traces in the Velence Mountain. 5. Frequent occurrence of galenite, pyrite, chalcopyrite sprinkled in the igneous rocks. 6. Occurrence of helium in the Székesfehérvár drilling. 7. Occurrence of contact metamorphic magnetite near Pátka. 8. Occurrence of barite veins in the mountain.

*Negative factors.* 1. Absence of cassiterite. 2. Absence of cobalt, nickel, bismuth. 3. The Falubattyán galenite occurrence genetically related to the Velence Mountain is inactive. 4. Verbal communication of *M. Vendel*, that the chemical composition of the Velence granite is differing from those connected with uranium occurrences.

Spectrographical vanadium researches in rocks of the Velence Mountain are in course made by the Institute's laboratory. If significant quantities of vanadium would be found, this might be an important factor according to the geochemical affinity of vanadium and uranium.

Pegmatites and sulphidic-fluoritic veins with a possible uranium content should be suspected in the contact metamorphosed envelop of the granite mass. In this respect the zone is to be considered, where overlying Tertiary cover is not too thick and the contact metamorphic rocks would be accessible by mining. This zone should be confined by geophysical measurements and perhaps even sulphidic ore or magnetite concentrations might be revealed. In this reason radio-active prospects are closely related with sulphidic ore and magnetite researches.

Actually we have to count only with the average 6 g/t uranium and about 60 g/t thorium contents of the Velence granites. Compared with the quantity of the granite mass this represents important uranium reserves. Considering that gold ores of similar concentration can be exploited profitably, it is not excluded that in the future granites of diffused uranium content might serve as uranium ores. Gold can be extracted from ores much easier, than uranium, but gold does not have any great industrial importance while uranium represents the indispensable atomic energy of the future, and its importance is increasing gradually. The actually stopped uranium deposits will be exhausted soon and then diffuse uranium occurrences will to be exploited. Uranium export is prohibited in each uranium producing country, uranium-import will be therefore impossible in the future. This indispensable and unsold raw material of the future's industry shall to be produced by each country within its boundaries. Uranium-production in a country might be therefore worth of unlimited costs.

#### Concentration possibilities of diffused uranium.

Possibility of uranium concentration is the central problem of uranium production. Until now we do not know how uranium is present in granites, which compound in which mineral. The stronger radiation of melanocratic varieties indicates that uranium is concentrated in the mafic heavy minerals. *Kirsch* succeeded (12. p. 165.) in raising uranium concentration by separation to hundredfold.

*F. Babanek* concentrated the scapolitic mica-schist wallrock of the Joachimstal lodes by subsidence methods: from 6358 kg material of 0.01% uranium he separated 226 kg of 0.3% uranium. At that time this procedure did not seem profitable. Weighing concentration possibilities it is to be pointed out, that above mica-

schist had probably coarser grains of uranium-bearing minerals, than the granite, but today ore-dressing technique is much more effective, than a simple subsidence.

In granites or specially in the Velence granite uranium-bearing minerals might be detected by surrounding pleochroic haloes. These could be best observed in biotites and have been ascribed to zircon grains. Zircon-inclusions are described from all constituents of the Velence granite by A. Vendl but pleochroic haloes were not reported. Author did not find haloes either in the Institute's slices. The question could be decided only by a greater number of slices. — *Osborn Hutton* determined the mineral grains in the center of the haloes of a New Zealand granite as monazite, xenotime and apatite.

It is a possible explanation that the Velence granites are too young to bear pleochroic haloes as they metamorphosed Carboniferous or probably Permian deposits.

Laboratory separation experiments are planned in order to reveal possibilities of concentration.

### General scientific results of the radiometric survey.

In the sketch map of fig. 5. distribution of radiation intensities is represented in the surrounding of the Velence Mountain. Activity of Pannonian beds and loesses is increasing towards the granite mass. Radiometric survey does not yield a summation of underground effects (like other geophysical methods) but only the intensity of radiation of the superficial layer. Radiation of deeper layers is totally absorbed by overlying strata. The radioactive «halo» around the Velence Mountain is to be explained by distribution of fragments of active rocks in the clastic sediments. Isoradiation curves can be constructed on the base of measuring data. Intensity of radiation has been expressed by the fraction: 
$$\frac{\text{soil radiation intensity}}{\text{cosmic radiation intensity}}$$

Three intensity-groups have been established: I. inactive rocks, relative intensity of radiation 0.0—0.1, II. weak radiation 0.1—0.5, and III. considerable radiation 1.0—3.0. According to present measurements the limestone and dolomite formations of the Buda Mountain and Balaton region belong with their adjoining sedimentary territories to the I. group. The II. group is formed by the surroundings of the Velence and Mecsek granites, while the III. group by these granites themselves.

Constructed isoradiation maps can be applied under favourable conditions in the study of sedimentation. It is a suitable «indicator» in determining distances of transport of clastic sediments. In the case of the Velence Mountain isoradiation curves reveal to what extent the material of the Velence granite participated in building up the Pannonian deposits. On this base even the percentage of granitic material can be estimated in the sediments.

In pedology measurements of soils radiation connected with some heat production may solve perhaps the problems of the so called «hot» and «cold» soils.

Biology, specially botany may also help in these investigations. Some sensible plants may produce on territories of strong radiation new variations due to the more intense bombing of the genes. Increasing of variation capacity according to intensity of radiation established by variation capacity statistical studies can be a proof of this hypothesis. In Belgian Congo no observation has been made about deficiency of vegetation on strongly radiating area.

### Improvement and widening of measuring methods.

Field measurements showed that results are strongly influenced by the shape of the uneven surface. In the future measurements are to be made in bore-holes. This way the measuring tube will be surrounded by a sphere of uniform radiation. By a modified instrument activities of succeeding layers can be measured in a bore-hole. Similar measurements have been made in bore-holes of oil fields. These methods ought to be applied even in Hungarian oil drillings. In the following years radiometric survey of our crystalline mountains first of all the area of the Mecsek granite is planned.

### Age determinations of igneous rocks in Hungary.

Spectrographical determinations of *M. Földvári* revealed that the lead-content of the Velence granite is about 0.01%. It is planned to separate necessary quantity of lead from the Velence granite and to examine its isotopes by mass-spectrograph in the Dept. of Physics, University Debrecen. This might enable us to determine the age of this granite. This might be of great geological importance and thus many related structural and ore-forming problems should be solved.

### Lines of further investigations.

In the reason of above consideration following research program has been made:

1. Laboratory separation and concentration experiments.
2. Geophysical survey of the Velence Mountain and surroundings directed from geological stand-point. On the base of these measurements preparation of the contour-map of the buried granite and other crystalline rock-masses. Exploration of the gravity, magnetic and conductivity maxima by drillings.

3. Geological and radiological survey of the Mecsek granite area.
4. Radiometric survey of drillings, application of methods in drillings of oil-fields.
5. Laboratory investigations for age determinations of rocks.

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## HOZZÁSZÓLÁSOK SZALAY SANDOR ÉS FÖLDVÁRI ALADÁR ELŐADASAHOZ.

*Kertai György*: Előadó szerint a kálcium radioaktív hatása jelentéktelen. Ez a gyakorlati geológusokat elkedvetleníthetné. 1941-ben megjelent irodalmi adatok szerint (*Zwergler, Strasser*) üledékes kőzetekben a K izotóp sugárzásának görbéje egyes rétegekre különböző lefutású, s így azok közötti megkülönböztetést lehetővé teszi. Homokos kőzetekben alig van K, míg agyagokban, ahol több adszorbeált K van jelen, jelentős értékeket mértek. 2—5% közötti K tartalmú kőzetek sugárzását *Geiger—Müller* számláló csővel gyakorlati sikerrel mérték Amerikában és a Szovjetunióban.

*Szalay Sándor* (válasz *Kertai György* hozzászólására): A K sugárzása mérhető, de az előadott vizsgálatoknál sokkal erősebb sugárzást mértek. Így statisztikusan kielégítő volt a 20 perces mérések eredménye, melyben a K sugárzása csak a hiba-határ nagyságrendjében szerepel. Háromórás mérésekkel a K sugárzását is meg lehetett volna határozni, de nem az volt a cél. Fúrásban nagyobb pontosság érhető el, mert a kozmikus sugárzás nem zavar.

*Kertai György*: Ugy tudja, a K sugárzása 2,7-re, esetleg 5-re is felmehet.

*Szalay Sándor*: A móri árokra merőleges szelvényekben végzendő méréseknél az árok peremét az aktivitás változása kijadná. A Szovjetunióban használták a radioaktív méréseket szerkezeti vonalak kimutatására. Sugárzás az árok mentén feltétlenül nagyobbak adódik. K sugárzás mérésével egykori szárazulatokat is ki lehet mutatni, aminek a dunántúli szénkutatásban lenne jelentősége.

*Szalai Tibor*: 1946-ban az Intézet vezetésének átvétele után feladatunk abbar láttá, hogy az újjépítéshez szükséges nyersanyagok kutatását előbbre vigyük. Nem zárkozhattunk vissza a tudós elefántesont-tornyába, míg az ország érdekei a sürgős gyakorlati kutatást megkívánják. Gyakorlati kutatásokkal ugyanis mindig kapcsolatosak új tudományos eredmények. Ennek a programnak megfelelően az Intézet több olyan nyersanyag kutatásával foglalkozott, melyeket eddig nem végzett. Mikor *Szalay Sándor* azzal a kéréssel fordult *Szalai Tiborhoz*, hogy a radioaktív kutatás számára területet ajánljon, a Velencei-hegységet, Mecsekét, Kőszeg—Rohonci-hegységet, az ország északkeleti részének paleozóis kőzeteit és a Duna homokjait ajánlotta.

A Velencei-hegységi kutatásokkal kapcsolatban megjegyzi, hogy az eredmények tudományos jelentőségén túl pillanatnyilag az a legfontosabb kérdés, hogy a gyakorlati probléma hogyan fogható meg. A geológiai kiértékelés a kontakt palák felkutatását indokolja, melyek elhelyezkedésére a geofizikai mérések adhatnak támpontot. Ezek után kerülhet sor feltáró fúrás lemélyítésére, esetleges felhalmozódások felderítésére. Az eddigi eredményekből is kitűnik, néhány előfordulás kőzetének (Retezi-kőfejtő, Erdősmecke) kiugróan magas effektusa. Ezek föllépésének okát ki kell kutatnunk, s ez remélhetőleg a célhoz is közelebb visz.

Az ország északkeleti részének paleozóos régeivel kapcsolatban felhívja a figyelmet arra, hogy ezek, mint azt az Északkeleti Kárpátokról szóló munkájában kifejtette, egy különálló kúszóbbhoz tartoznak. Nagy örömeire szolgált, hogy a *Quarterly Journal*-ban (1946) *Sujkowsky* a Pripjet mozsarak környékén végzett részletvizsgálatairól be-