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C O N T E N T S

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INTERNATIONAL URANIUM RESOURCES EVALUATION PROJECT (IUREP)

SUMMARY

Greece, with an area of 131 944 km^2, has been actively explored since 1971 under a programme of co-operation with UNDP and IAEA on which close to US $1 million have been spent so far.

The programme is focused on the Rhodope Precambrian massif, which is the most attractive structural unit from the geological point of view.

The indications available at present, and which have been known for a long time, are also to be found in this unit. They are associated either with Tertiary continental volcanism or with detritic sediments in basins covering this massif. So far there is no evidence of their being of any economic value.

The paucity of data available on the basement of the Rhodope precludes any prediction as to the possibility of its containing Precambrian uranium mineralizations. Onemight perhaps think in terms of mineralizations of the alaskite or alkaline complex type, or also of vein-type deposits.

But it is primarily in the deposits associated with tertiary trachy-rhyolitic volcanism that we have most confidence, especially in the Rhodope massif and the Vardar region but possibly elsewhere in the Hellenides as well.

All things considered, we place Greece in Group 2 of the IUREP classification.

I. INTRODUCTION AND GENERAL GEOGRAPHY

Greece, which has an area of 131 944 km^2, is located at the southern end of the Balkan peninsula, between 36° and 41° N latitude.

In terms of relief, Greece is essentially an Alpine mountainous country, 68% of whose territory lies at an altitude higher than 200 m. It consists

of a profusion of islands which form about 19% of the country's area and it has some 15 000 km of coastline.

In the north of the country lie the plains of Thrace and Macedonia, hemmed in between the Rhodope massif on the north and the Khalkidiki peninsula on the south.

The remainder of the country consists of the Hellenic peninsula, which forms a vast littoral platform that is greatly fragmented and dissected and the main orographic axis of which is formed by the mountains of the Pindus range and of the Peloponnese - a prolongation of the Dinaric system, the culminating point of which is Mt. Olympus (2918 m). These massifs, which are difficult of access, isolate eastern Greece from the western part and precipitation is concentrated on them.

Actually, the Mediterranean-type climate is warmer and the countryside is more verdant in western Greece (Corfu, 1365 mm/yr) than in eastern Greece, which is drier (Thessalonica, 435 mm/yr), and in the interior plains with their torrid summers.

The inadequate railway and road systems represent a serious obstacle to the development of the country, in spite of the important part played by navigation in the Greek economy.

II. GEOLOGY OF GREECE IN RELATION TO POTENTIALLY FAVOURABLE URANIUM BEARING AREAS

Greece is one of the most mountainous and dissected countries in Europe. It comprises a continental aggregate, the eastern part of which is occupied by old peneplained massifs and faces the eastern chains, and by numerous islands.

Two geological units can be distinguished:

1. The Rhodope massif, in Thrace and Macedonia, which is part of the "Serbo-Macedonian" massif formed of a Precambrian metamorphic basement which is also affected by Alpine metamorphism;
2. The Hellenides*/, part of the Dinaric branch of the Alpine system, consisting of secondary and tertiary geosynclinal sediments, involved in Alpine-type foldings and overthrusts.

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*/ Translator's note - This designation is not used in any of our reference works.

The Rhodope massif is composed mainly of gneiss, micaschists, marbles and ultrabasic aggregations whose Precambrian age has been determined radiometrically. It is intersected by intrusions of Pretertiary granitoids. Lying discordantly on this basement are Jurassic neritic outliers and also flysch-type terrigenous series to the replenishment of which it has contributed. A majority of authors are of the opinion that the Rhodope massif, for the most part, remained emerged during the Mesozoic and Cenozoic.

Molasse-type terrigenous series (Didymothikon basin) lie discordantly on the Precambrian (Eocene transgression) and this type of detrital sedimentation continues to the present time.

Known Oligo-Miocene features are a powerful trachyandesite (trachyrhyolite?) volcanism and granodiorite intrusions.

It has become traditional to distinguish between two units in the Rhodope massif: the Rhodope massif proper, as it has just been described, and - continuing along its western edge and corresponding to two thirds of the Khalkidiki peninsula - a region known as the "Serbo-Macedonian massif". This region differs from the rest of the Rhodope massif in that it has been affected very intensively by the Alpine orogeny. It has been fractured generating a schuppenstruktur overthrusting ~~into shales which were discharged onto~~ the Hellenides unit to the west as well as ~~onto~~ the Rhodope massif to the east.

Mention should also be made of the formation of a post-Hercynian and intermediate pre-Triassic, metamorphized, rhyolitic volcano-sedimentary ensemble.

It should also be noted that the islands of the north-eastern and eastern part of the Aegean Sea form part of the Rhodope unit.

The Hellenides. The transition from the Rhodope massif in the broad sense to the region of the Hellenides is via the zone of the Vardar. This is the most internal zone of the Hellenides and comprises an aggregation of the "coloured melange" type formed of ophiolites, radiolarites, globigerine marls and flysch. It also incorporates fragments of pre-Mesozoic basement (calc-alkaline granites 290 million years old have been dated). This zone is characterized by the fact that it was kratonized and incorporated in the Rhodope block as from the Upper Jurassic. It was then subject to a series of magmatic reactivations: alkaline rhyolitic

volcanism of monzonite tendency and monzonite plutonism of the Upper Jurassic, granitic plutonism, volcanism and rhyolitic to dacitic hypovolcanism of the Eocene.

On the whole, the Hellenides are formed of sediments of the detritic carbonated type in association with episodes of magmatism (basic to acid) and metamorphism (greenschist type).

In terms of paleogeography, we can distinguish a series of zones stretching in NW-SE direction in the continental part and then assuming the curvature of the Aegean arc in the islands. Each zone is characterized by a different kind of sedimentation: neritic, pelagic, carbonate-dominated, from the Mesozoic to the beginning of the Cenozoic, and terminating in a terrigenous episode which is generally intra-Cenozoic (sandstones, flysch-type marls). Associated with these features are a basic magmatism (diabases) and large ophiolitic massifs dating from the Upper Jurassic.

It would appear that the main (end-Eocene) tectonic phase was responsible for the fundamentally allochthonous character of the so-called internal zones (in the NE) over an external ensemble of relatively autochthonous character (in the SW), as well as for the metamorphism of the glaucophane-greenschist-type metamorphism.

An Oligo-Miocene phase, characterized by the formation of folds with a large radius of curvature, leads to the outcropping of the Paleozoic sole of the underlying nappes or units by means of anticlines, while in the synclines we find the development of a pronounced molasse-type sedimentation which becomes increasingly recent as one proceeds from the NE towards the SW, from the Eocene (Thrace) to the Miocene (Aegean arc). In the Vardar region and the islands of Lemnos and Lesbos granodiorites and trachyandesites have been identified.

In the Plioquaternary the sedimentation, generally of the detritic type, was presumably guided by the play of faults (system mainly NW-SE/NE-SW) and deposited in the continental (Macedonia, Thessaly) or marine (Corinth) trough faults. This is associated with an andesitic-basaltic volcanism in continental Greece (Ibar Valley) and in the islands (Santorin).

In the light of current knowledge on the subject of uranium in the Alpine chain of Europe, where the concentration of uranium is associated strictly with Paleozoic - or even older - formations, there is little reason

on the face of things to expect the formation of uranium-bearing deposits in the Greek system, where sedimentation generally begins in the Triassic. The major targets would be the windows, by means of which it would be possible, through the nappe structure, to discover the outcropping of formations which were hitherto generally considered as Paleozoic or pre-Paleozoic. This problem of metamorphic outcroppings emphasizes the fact that we still do not know what portion of the series is really Paleozoic and what are the portions of the series which, although reputedly Paleozoic, are probably metamorphized Mesozoic formations.

Actually, in Olympia, in southern Euboea, in Attica and in Crete they are secondary or tertiary formations lying below the Paleozoic and which appear through windows below the nappes. The dated Paleozoic presumably represents only the sole of the Alpine nappes and gives rise to the question of the existence of a pre-Alpine metamorphic basement - other than the Serbo-Macedonian massif.

III. PAST EXPLORATION

Prospecting for radioactive minerals in Greece started in 1952 and was carried out under the authority of the Greek Atomic Energy Commission (GAEC) and the Institute for Geological and Subsurface Research (IGSR).

In 1953-54 a USAEC mission worked on already-known anomalies and decided that the Rhodope region*/ was the main target. The French missions in 1959 and those of the IAEA and the CEA in 1969, as well as that of Professor Hügi in the same year, came to the same conclusions. During this period the IGSR engaged in a number of prospecting activities, the most important of which was an aerial magnetometry and scintillometry campaign (ABEM Company, summer of 1966). And lastly, an agreement relating to an uranium exploration project was signed between the United Nations (UNDP), the IAEA and the Greek Government in 1971. It provided not only for the evaluation of Greece's uranium potential but also for the training of personnel. This prospection programme is concerned with central and eastern Macedonia and with Thrace.

IV. URANIUM OCCURRENCES AND RESOURCES

Almost all the uranium occurrences now known in Greece are to be found in the Rhodope massif, which contains considerable lead-, zinc- and copper-

*/ Of 17 known occurrences, 12 are in Macedonia and Thrace.

sulphide mineralizations as well as occurrences of gold, silver, antimony, molybdenum and iron. In addition, lignite and coal are to be found in the sedimentary covers.

The main uranium-bearing occurrences are the following:

- Vathi (Kilkis region) to the west of the Greek part of the Rhodope massif. This is a breccia affecting a kaolinized volcanic formation overlying metamorphic schists. The fissures of the breccia and the kaolinized rock are covered with a torbernite mineralization that is not very abundant. This breccia is fairly rich in secondary minerals of copper and also in specularite and limonite.

- Aemonion-Kotyli: uranium-bearing coal deposits (up to several hundred ppm U) in a small Eocene basin. The coal reserves are of the order of 0.5 to 1 million tons (and consequently the uranium reserves amount to a few hundred tons). This basin, which is located towards the centre of Thrace, is reported to be close to a Bulgarian uranium district.

Mention should also be made of the radioactive lignites of Serrai (10 times the background).

- Kirki: in eastern Thrace, this vein-type Pb-Zn-Cu mine located in quartz gangue is encased, according to some sources, in flysch and, according to others, in effusive Tertiary rocks. Abnormal concentrations (up to 940 ppm U_3O_8) have been determined but no uranium-bearing minerals are reported to have been observed;

- Radioactive slag, apparently dating from the time of Alexander the Great, has been found north of Serrai;

- Radioactive rhyolites have been observed at ....bophos (illegible) near the Turkish border.

Greece has not provided any information on its uranium resources, probably due to the fact that no really economic occurrence is known at present.

Up to the end of 1976, the total expenditure on prospecting in Greece was over 0.9 million dollars.

V. PRESENT STATUS OF PROSPECTING

The programme of co-operation with UNDP and IAEA is being continued. Expenditures for 1977 will amount to $432 000.

VI. POTENTIAL FOR NEW DISCOVERIES

There seems to be a general consensus that in Greece the Rhodope massif is by far the most promising structural unit for the presence of uranium deposits. This assumption is supported by the fact that practically all the known occurrences are located there and by the (presumed) presence of deposits in Bulgaria in the northward extension of this unit.

What types of uranium deposits are likely to be found in this unit?

So far no pre-Alpine uranium mineralization (other than refractory minerals in alluvia) appear to have been identified in the Precambrian crystalline basement of the Rhodope massif.

All the known indications are associated either with tertiary volcanism (Vathi, Kirki, Lycophos) or with processes of concentration by reducing sedimentary environments (Aemonion-Kotyli, Serrai) due to uraniferous solutions of unknown origin (leaching of the regional basement or derived detritic series or else more or less remote association with tertiary volcanism?) We have not found in the documentation any information relating to the possibility of uranium concentrations in the tertiary detritic formations of the classical type found in the western United States.

The fact that the Rhodope basement belongs to the Precambrian is in principle a favourable characteristic for this part of Europe, as far as the prospects of finding uranium deposits are concerned. From this point of view, however, the old age of the Precambrian, and also its structural character and its lithology, are important types of information which have not been available to us for carrying out this work.

In other words, it is difficult for us to evaluate accurately what types of Precambrian uranium deposits the Rhodope basement would be likely to contain and, therefore, to draw conclusions as to its capacity for uranium mineralization.

Tentatively, we might think in terms of the following:

- Deposits associated with alaskites or, conversely, alkaline complexes, if the ultrabasic rocks of northern and eastern Thrace and the island of Lesbos really are Precambrian and depending on whether they represent orogenic zones or rifts (this seems less probable);
- Vein-type deposits, especially those associated with the Precambrian granites (if they really are such); it would probably be the least metamorphic mobile zones which would be the most promising targets;
- Hercynian granites have been identified, at least in the Serbo-Macedonian zone; vein-type mineralizations might also be associated with them.

But it is the mineralizations associated with the Alpine orogenesis which seem to us to be the most valid targets, namely:

- Possible uranium mineralizations in the detritic sediments of the Mesocenozoic basins covering the Rhodope basement in the broad sense;
- Mineralizations associated with Alpine granitoid intrusions, especially when the encasing rocks are schists which are not strongly metamorphic (type of mineralizations found in the pre-granitic peribatholithic schists, as in Spain);
- But in particular mineralizations associated with the continental volcanism, especially of trachy-rhyolitic tendency; this type of volcanism is apparently to be found in the Rhodope massif; the continental sedimentary basins associated with volcanism of this kind would be especially attractive.

The Hellenides represent the type of structure which has thus far not proved to be very abundant in uranium deposits, as indicated at the end of section II above, except however in the zone of the Vardar which, just like the Rhodope massif, might have mineralizations associated with its Alpine volcanism.

Consideration could also be given to an investigation of the metamorphic "soles" of the nappes and, if necessary, of the pre-Triassic series. But

here, again, the volcanic aspect (trachy-rhyolitic tendency) is doubtless the most reliable one. Moreover, it is in connection with the old nuclei that the chances of finding uranium are greatest.

What uranium potential would definitely compensate for the systematic prospection of all the targets mentioned?

The Rhodope massif and the bordering zone of the Vardar account for an area of only some 20 000 km^2 in continental Greece. It is true that we must add to this area that of the emerged lands in the north-eastern and eastern part of the Aegean Sea.

All things considered, in the present stage of our knowledge of the geology of the Rhodope-Vardar ensemble and the geology of the uranium in this domain, we shall go no further than to place Greece in Group 2 of the IUREP classification.

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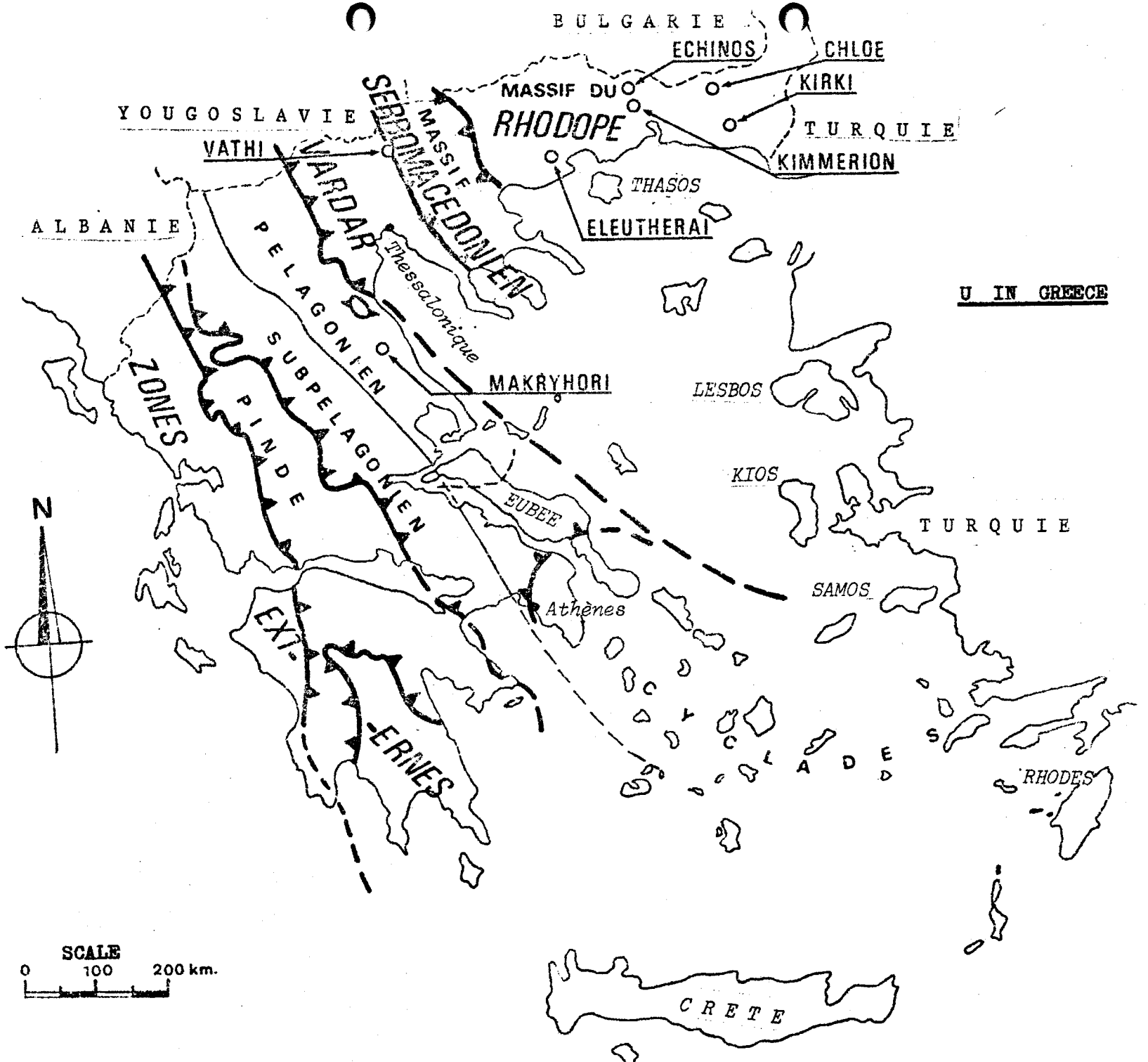
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