The Paleogeographical, Lithological and Structural Controls of Uranium Occurrences in the Alps

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Introduction

The prospecting work carried out on the Italian side of the Alpine Range during the last fifteen years have led to recognize a large number of uranium occurrences (Mittempergher, 1966). Other occurrences have been found in the French, Swiss, Austrian and Yugoslav Alps (Hügi and ot., 1962; Hügi, 1967; Barreau, 1959). As a common feature, all these occurrences are contained in rocks of late Paleozoic or Lower Triassic age.

A second group of uranium occurrences in fissures and in veinlets in the crystalline basement rocks is quite less interesting and important. Numerous studies have so far been performed about these mineral deposits, whose distinctive features are now fairly well known and described at sufficient extent (Fig. 1).

Some supplementary efforts, however, are necessary for better understanding of the minerogenetic processes of uranium, which took place, at a given geological moment, over a very large area, approximately 1000 by 400 kilometers wide. Some attempts in this direction have been made (Marinelli and Mittempergher, 1962) but only recently the geological informations have been acquired for an overall study in order to obtain both, the outlines of the "regional" features of the minerogenetic processes of uranium and the correlations with the more general uranium ore genesis in Hercynian era of Europe (Mittempergher, 1970).

THE GEOLOGY OF URANIUM OCCURRENCES IN THE POST-HERCYNIAN BASIN

The uranium mineralizations occur in the volcanites and in the continental or littoral deposits of Permian and Lower Triassic ages of the whole Alpine area.

These formations overlie unconformably the eroded crystalline basement and represent the magmatic and sedimentary products that affected a large subsiding basin of late and post-Hercynian ages.

The uranium mineralizations are divided in previous papers (D'Agnolo, 1966; Mittempergher, 1958) as follows:

— hydrothermal mineralizations in the volcanic rocks of the Lower Permian (Fig. 2);

— stratiform mineralizations in the continental sandstones of the Permian;

— stratiform or lenticular mineralizations in the littoral deposits of the Permo-Triassic.

Here I do not describe in detail the features of above-mentioned mineralizations that are pointed out in several specific works. I recall only that the study of these mineralizations has often required the reconstruction of the geological and minerogenetic conditions of ore deposits deformed and regenerated by Alpine metamorphism.

This is the case of that part of the post-Hercynian basin subjected to the complex Pennidic tectonism in Alpine age.

It is very hard to assemble in an integrated picture a paleogeographic reconstruction, tending to comprise all environmental and structural varieties of the Alpine zone during Permian and Triassic. This would require a preliminary reconstruction of the Hercynian land and of its structural changes over extremely large areas. On the other hand, the paleogeographic reconstruction is complicated not only by the difficulties of "spreading out" the Permian and Triassic formations incorporated into the complicated movements of the folds during the Alpine orogenesis, but also by the difficulty in correlating the different areas of the zoning of

Reference to Fig. 1

TECTONIC UNITS OF THE ALPS

Helvetides

Pennides

Austrides
L) Northern Limestone Alps

Prealps

Southern Alps

Dinarides

Pre-Alpine crystalline basements

Po-Molasse and Vienna basins

Granitic batholits

URANIFEROUS MINERALIZATIONS

⊕ Hydrothermal in permian volcanites

○ Epigenetic peneconcordant in permian or lower-triassic continental sandstones

● Symmetamorphic, remobilizated in Alpine age, occurring in permian and permo-triassic sediments

◒ Hydrothermal in veins, cataclasites and mylonites

⬢ Pyrometasomatic

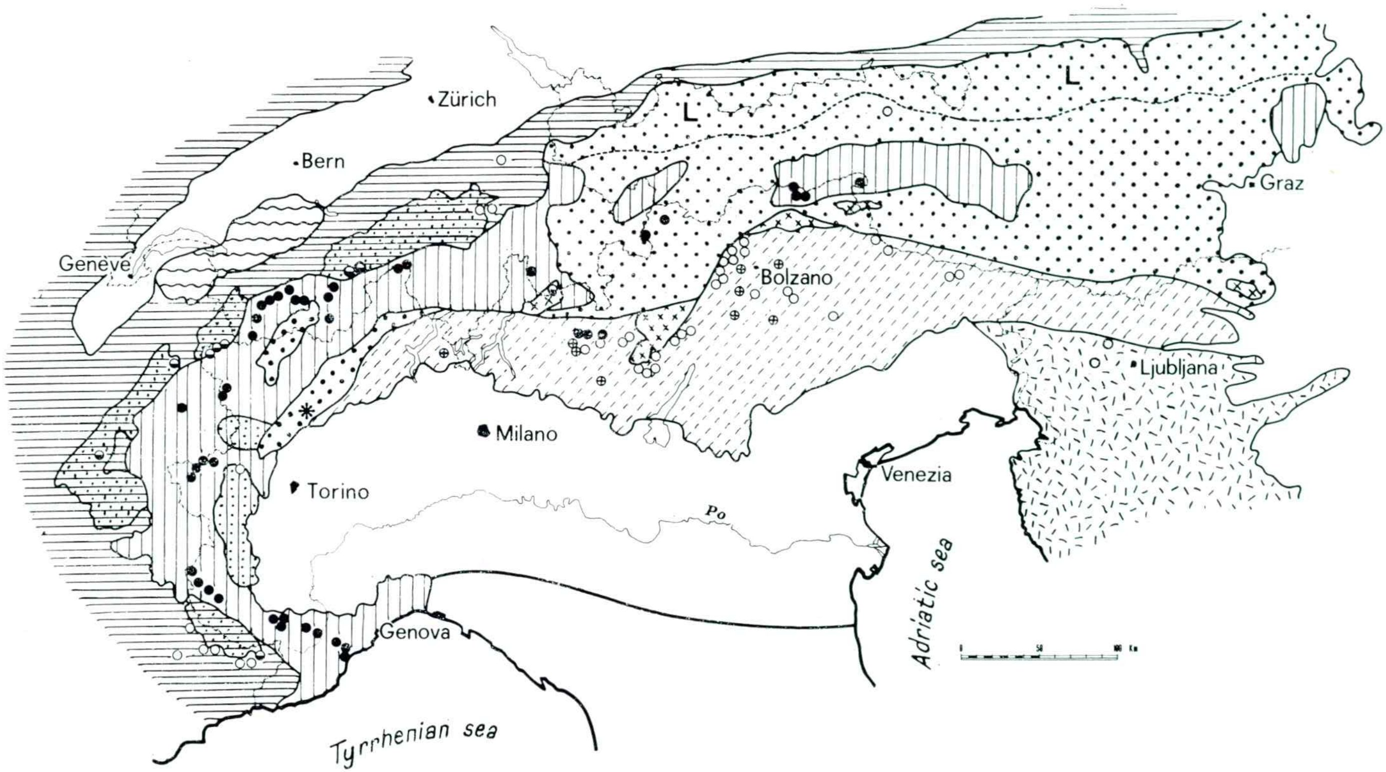

Fig. 1. Uranium occurrences in the Alps

Alpine tectonic. Such zonning occurs not only longitudinally with respect to the axis of the orogen but, still asymmetrically, also along that axis.

However, in view of the purpose of this study (drawing a picture of the general characters of the environment of uranium ore genesis in the late Paleozoic), a highly simplified description is deemed sufficient. For such purpose, I have utilized paleogeographical sections crossing the central and eastern parts of the Alps where it is easier to correlate the Permo-Triassic environment and the Alpine tectonic units.

The area at present time occupied by the Alpine Range corresponds roughly to one sector of the Hercynian foreland, the basement being formed by metamorphites and Hercynian granites. This area has undergone an extended erosion process. Subsidence took place by fracturing and displacement of the eroded massif, with the formation of two separated basins: a Southern one known as "alpine type" and a Northern one as "germanic type" (Fig. 3).

The two basins were separated by a structural "high" corresponding coarsely to the zone of the Pennide nappes. A sedimentation of continental character began in both basins during the Lower Permian. A magmatism started simultaneously in both basins, first in the form of epigranites (average age 280 MY), later in the form of acid volcanism (indicative age 265 MY). In the "Alpine basin" the processes of continental sedimentation, with sediments predominantly of an alluvial nature, ended in the period ranging between the Upper Permian (Bellerophon zone) and the Lower Triassic (Werfenian), with marine and lagoon epicontinental sediments (Fig. 4). In the "Germanic basin" the marine ingression took place in the Lower-Middle-Triassic (Muschelkalk).

In the transitional belt, the whole zone of the Pennide and "Briançonian" nappes, the subsidence took place very late: the continental Permian is very weakly represented. The marine ingression of the Permo-Triassic took place with recurrences and extreme elaboration of the sediments (formation of the Triassic quarzites). The Triassic facies are in part of the "alpine type" and in part of the "germanic type".

The whole Pennide and Southern Alps area then evolved into the Alpine geosyncline (Fig. 3). In this overall picture, the uranium deposits of the Alps are located partly in the original basin of the Southern Alps, partly in the area of structural "high" of the Pennide nappes (De Sitter, 1959).

In the thickest part of the Post-Hercynian continental series, sedimentary and volcanic, uranium occurs in the deeper levels and has an epigenetic character. In the Pennide zone, where the Permo-Triassic series is very reduced, uranium concentrations are partly syngenetic and are located in the upper parts of continental sediments at the transition to the epicontinental marine formations; partly they are epigenetic with the characters of the Southern Alps basin deposits.

Uranium occurrences related with "germanic facies" of the Triassic are not known in Italy; sparse and poorly documented reports suggest that in this series uranium ore bodies occur, as i. e. those of the "Buntsandstein" at Kitzbühel, Austria.

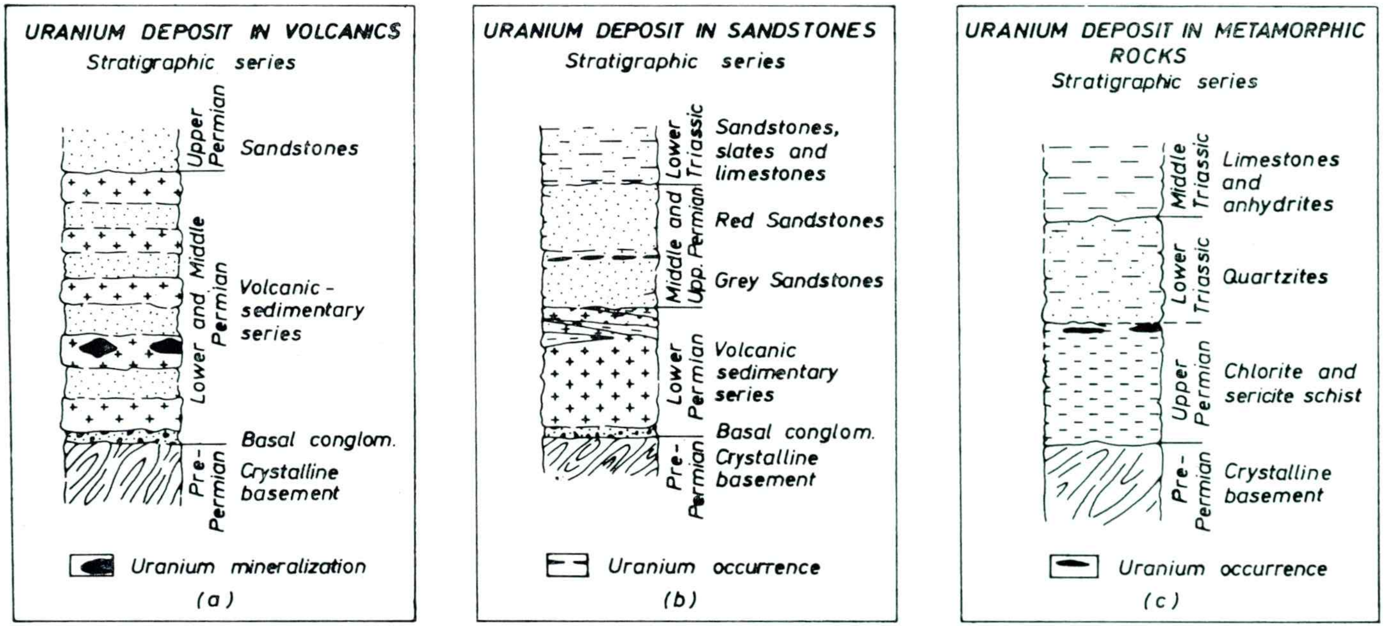

Fig. 2. Uranium deposits in volcanic rocks (a), sandstones (b) and metamorphic rocks (c)

In Fig. 1 it is possible to note that the mineral occurrences related to the thickest Permian zones are the most numerous and important.

The general feature of the uranium province of the Permian and Permo-Triassic in the Alps is the fact of being located in a pregeosynclinal basin. This was a basin open southwards to the Thetis Sea; the time of the sedimentation of the continental facies is comparatively short. According to the current information, setting the age of volcanites at around 265 MY and the Ladinian-Carnian limit at more than 230 MY, the continental and littoral sedimentation lasted not more than some 30 MY. The pregeosynclinal character of the basin and the fact that the direction of the displacement has always remained downward (subsidence), have determined the nature and quality of the sedimentary uranium occurrences. These mineralizations are small, very numerous and are distributed in a number of levels, somewhat heterogeneous in geochemical paragenesis. On the whole it seems to be evident that the processes of ore-deposit reconstitution through remobilization and concentration of the ore bodies in subsequent stages and hydrogeological situation, didn't take place. These processes often account for the economic importance of the uranium deposits in the intracratonic and intermountain basins.

A first general conclusion which is confirmed also in the case of the Permian and Permo-Triassic of the Alpine area is that the pregeosynclinal basins are less important for the potential of uranium concentrations with regard to other types of basins (intracratonic, intermountain).

Distribution of uranium mineralizations in the Permian basin of the Southern Alps

In the preceding sections we have discussed the distribution of uranium ore bodies in the different "transversal" zones of the geosynclinal basin, i. e. in the "germanic facies" area of Triassic in the intermediate area of the Pennide nappes, and in the Southern "alpine facies" area of Triassic.

A better understanding of the minerogenetic processes derives from a study of the distribution of uranium occurrences within an invididual structural and paleogeographic area.

Such a study can well be carried out with respect to the Southern Alps area, characterized by the presence of both a considerable number of ore bodies and geologic and tectonic conditions which are comparatively easy to interpret. Among the different longitudinal zones of the pregeosynclinal basin, that of the Southern Alps was the area of fastest subsidence, and the Permian and Triassic are largely represented in it. Now a stratigraphic reconstruction of the lithofacies and of their thickness has shown (Bosellini, 1965) that the Southern Alps area can be subdivided into five sectors, in which the Permian and Triassic formations display widely different developments. The five sectors, perpendicular to the axis of the geosyncline and to the Hercynian directions, are alternating areas of faster and slower subsidence (Fig. 5). Three of these areas are structural "highs", in which the thickness of the Permian and Triassic

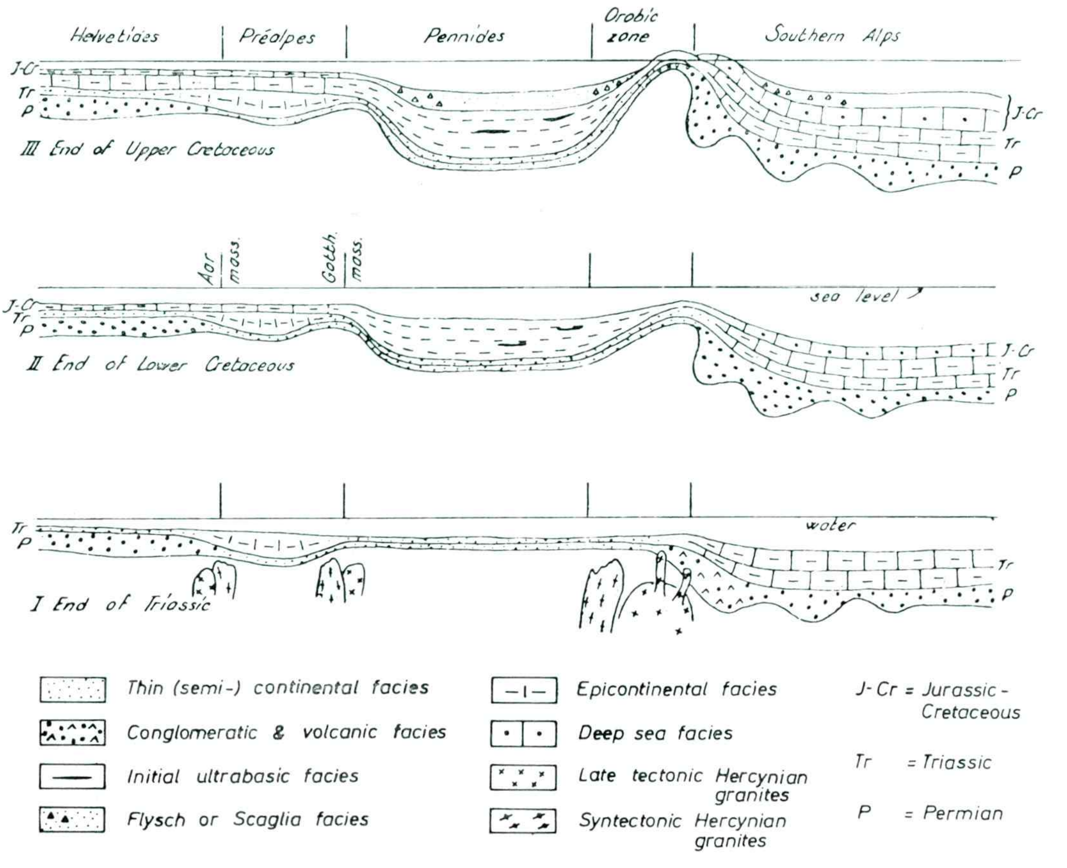

Fig. 3. Schematic development of Alpine basin during the Mesozoic era (After de Sitter, 1959)

series is relatively limited (1000 to 3000 meters). These three structural "highs" are those of platform of Lugano, Adige and Julian Alps. Between them are located two areas of structural trough, in which the Permian and Triassic series are as thick as 6000 to 8000 meters. The areas of structural "low" are the Lombard and the Veneto-Carnian basins. Analysing the distribution of uranium occurrences with regard to these structural divisions of the Southern Alps (Fig. 5), we find that uranium is largely concentrated in the "structural low" of the Lombard Alps, where the Permian series is thickest. In particular, the uranium ore bodies are more frequent in the eastern slope of the Lombard basin, near the Adige structural "high". Generally, therefore, we may conclude that the uranium mineralizations contained in the Permian and Triassic of the Alps are typical for pregeosynclinal basins and that, within these basins, they are concentrated in the areas of fastest subsidence, where the lithologic series is thickest.

The relationship between uranium mineralizations in volcanites and in sediments

Volcanites are a constant component of the Permian series of the Southern Alps. These volcanites, which are related to the oldest levels of the Post-Hercynian series, are present in the three westernmost structural zones, in the Lugano structural "high", in the Lombard structural "low" and in the Adige structural "high". Volcanites often contain uranium ore bodies, as described above. If we compare the distributions of volcanites and uranium mineralizations contained in the Permian sandstone, we observe a close connection; this connection is obviously more evident between ore bodies in the volcanites and ore bodies in the sandstones (Fig. 6). Since the sandstones are younger than the volcanites and are made up in part of volcanite fragments, it is clear that the mineralizations in the sandstones are genetically related to the volcanites and, in part, to those contained in the latter ones.

Outside of Southern Alps it is not possible to localize the Permian volcanites owing to Alpine metamorphism. Nevertheless, in the Marittime Alps and in the Esterel, the correlation between volcanites and uranium mineralizations is very close.

Without entering upon the matter of minerogenetic models, a subject which lies outside the purpose of this paper, it would seem that the facts outlined above suggest that a remarkable importance for the occurrence of uranium may be attributed to the rocks of the late-Hercynian acid volcanism of the Alpine area. This importance indeed originates both from the uranium occurrences within the volcanic rocks themselves and from the mineral deposits in the sediments.

Two conclusions may be drawn up from this recognition. A first conclusion concerns the problem of the areal distribution of uranium mineral deposits: carrying further the points raised above, we can say that uranium ore bodies tend to concentrate in the areas where volcanites occur. The greatest concentrations are found in the "structural lows", where volcanic rocks are extensively present. A second conclusion concerns the problem of the Hercynian uranium province of Central Europe — a province in which, as it is known uranium is particularly associated with the late-Hercynian magmatic massifs. Also in the case of the Alpine area the late-Hercynian magmatism is clearly uranium-bearing. Whether this fact is attributable to magmatic and hydrothermal causes resulting therefrom, or it is due to the particular geographic evolution of the pregeosynclinal basin, can be a matter of speculation.

The Alpine regeneration and redistribution of uranium occurrences

It has been recognized that uranium mineralizations are more numerous and important in the areas where the subsidence rate of the post-Hercynian basin is higher and in the areas with more intense volcanic activity. Furthermore, it has been noted that the development of the post-

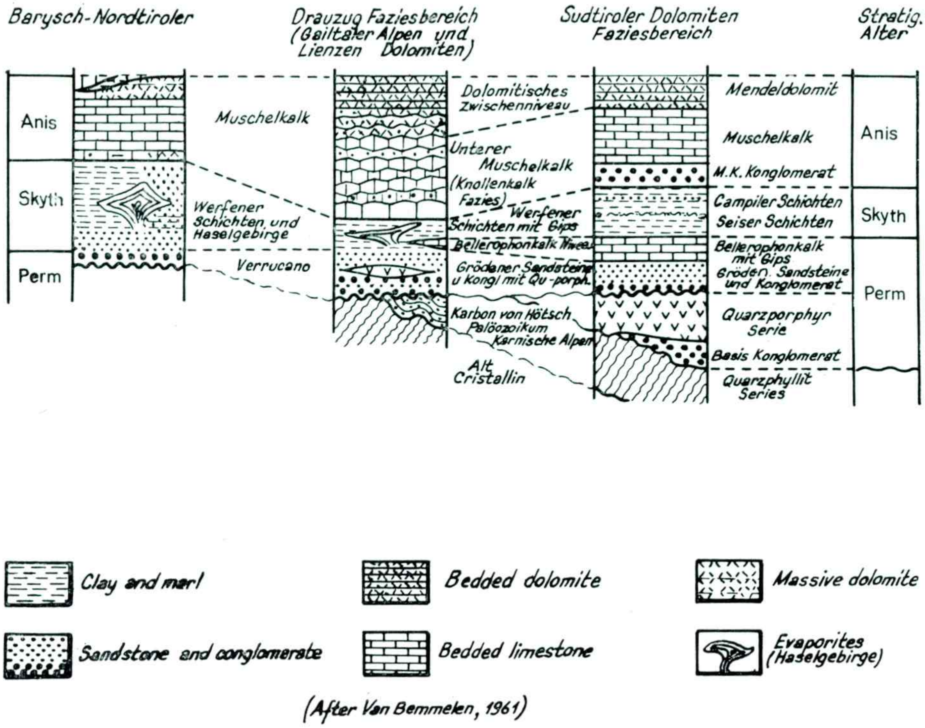

Fig. 4. Schematic columnar sections of Northern Limestone Alps (left), the Drauzug (middle) and the Southern Alps (right)

Hercynian basin into a geosyncline has limited remarkably the importance of uranium ore genesis.

Actually it has conferred to the rocks a diagenetic feature and has determined therefore a different kind of deformation and of hydrological behaviour. In the area of Pennidic nappes and along the margins of the great austroalpine dislocations (Orobic line), the alpine stresses have differently metamorphosed the host rocks and have regenerated the ore deposits. The intensity of this action was different in the different areas of the Pennidic nappes. Where the metamorphism was slight the ore deposits maintained a stratiform or lens-shaped structure; on the contrary, where the metamorphism was of a higher grade, the mineralizations were even completely regenerated and assumed a typical synmetamorphic feature.

Similar examples of remobilizated and regenerated ore deposits have been recordered in relation to mylonite bands and thrust-zones. In any case, the tectonic and metamorphic processes have been a further cause of dispersion of the uraniferous occurrences. In Fig. 1 are shown the Permian or Permo-Triassic uranium mineralizations regenerated in Alpine age.

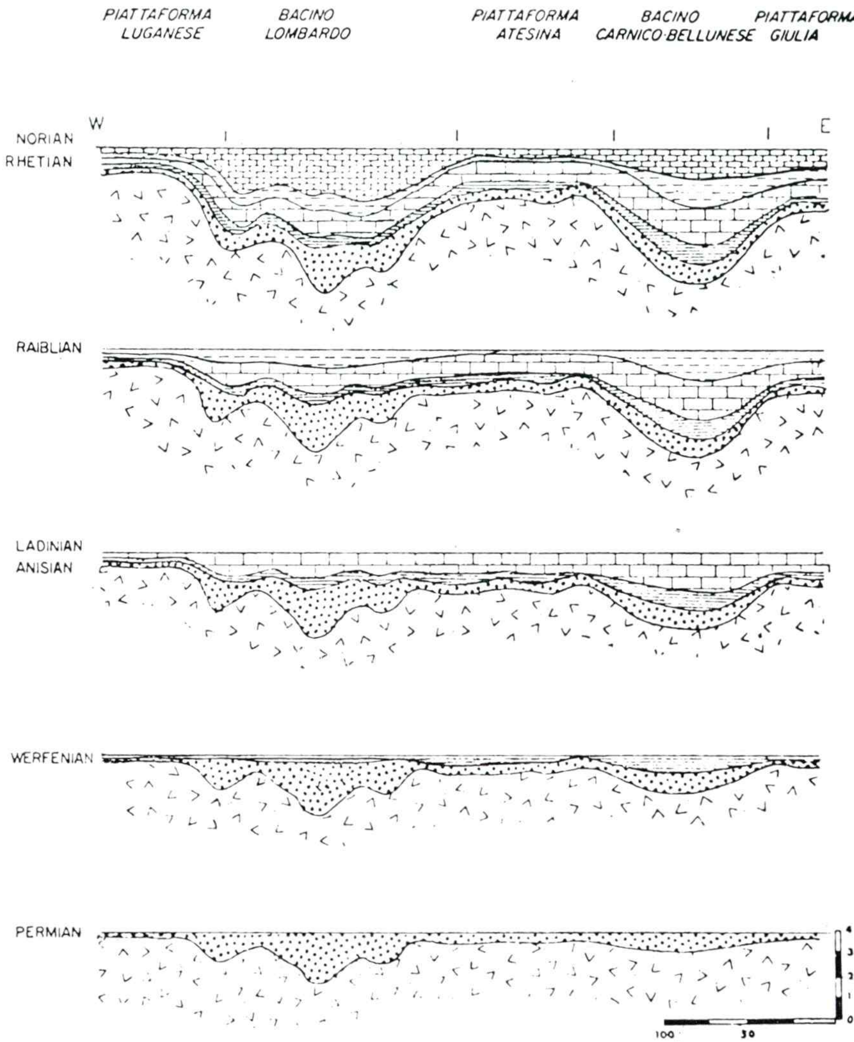

Fig. 5. Sedimentary basin during the Permian and Triassic periods as represented in longitudinal stratigraphic sketches of the Southern Alpine Range (After Bosellini, 1965)

THE URANIUM OCCURRENCES IN THE CRYSTALLINE BASEMENT OF THE ALPS

Fig. 1 shows that few uranium occurrences are connected with the blocks of crystalline basement involved into Alpine nappes. Typical examples are represented by the Helvetidic blocks. For the description of these mineralizations I recall just published works. I remember only that

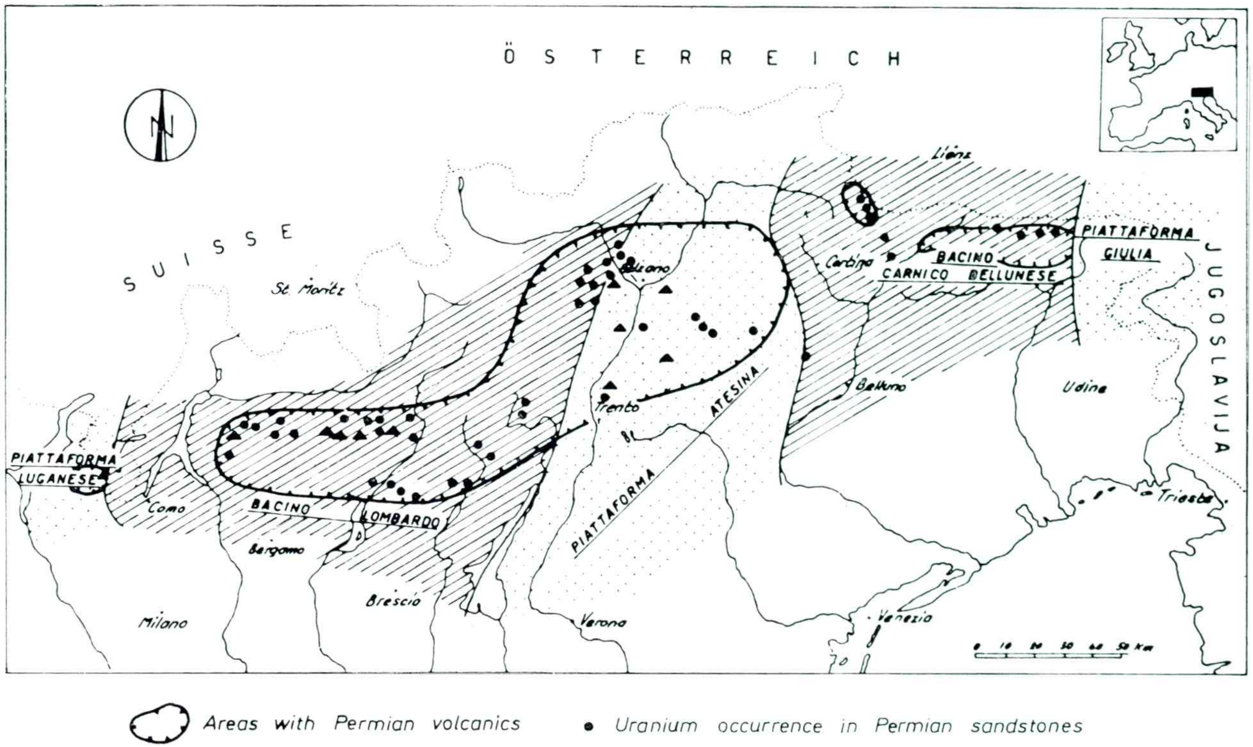

Fig. 6. The main tectonic units in Southern Alpine Range during the Permian and Triassic periods

generally they represent mineralizations in fractures and mylonites of late or post-Hercynian age. Their paragenesis is typically epithermal. The are controlled by a late or post-Hercynian tectonism and were subjected to remobilization processes in Alpine age. Therefore their age varies from 190 M.Y. (Gordolasque) to 90—80 M.Y. (Monte Bianco).

These mineralizations, the most typical of which are localized in the Monte Bianco Massif, may be related to a common genetic source, the same of the uranium occurrences of the Asturian-Vosgian phase of the French Central Massif. Contrary to the acid volcanites that represent the extrusive equivalents of such plutonics, these ones have no practical importance. On the whole, the Hercynian plutonics of the Alps are poor in uranium occurrences.

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SUMMARY

The uraniferous deposits discovered in the Alpine area can be subdivided into two groups.

The first group, the most important for the number of occurrences as well as for their economic importance, includes mainly stratiform peneconcordant ore bodies, generated in the post-Hercynian volcano-sedi-

mentary basin during the Permian and the Lower Triassic periods. The distribution of these mineral deposits is connected with the features of the evolution of this basin. In the Southern Alps, where the Permian continental and volcanic series has a remarkable development, the mineralizations are mainly localized in the volcanites of Lower Permian and in the lower horizons of Middle Permian sandstones. In the northern areas of the Alps, where the Triassic sediments are as "germanic" facies, the few mineral occurrences discovered are localized in the sandy levels of Upper Permian and Lower Triassic.

In the Pennide Region, representing the primary transitional area from "germanic" to alpine facies of Triassic, the uranium occurrences are localized both in the Permian and in the Triassic formations.

The main mineral deposits occur in the Lombard basin, where the Permian series is thicker. Furthermore, it has been found that the most important and widespread mineral deposits are distributed in proximity of late Hercynian volcanic masses. The importance of late Hercynian magmatism for uranium in Europe is confirmed. During the Alpine diastrophism all these mineralizations were partially diagenized, metamorphosed and regenerated. The uranium ore deposits of the Permian and Triassic in the Alps are of limited economic interest, since they took place in a typical pregeosynclinal basin. Such basins are quite less suitable than the intermontane or intracratonic basins. Indeed, in the last ones most of the world uranium reserves occur.

In the second group of mineralizations, all of no economic interest, the occurences connected with mylonites and post-Hercynian tectonic structures in the blocks of crystalline basement occurring in the Alpine nappes are included.

DISCUSSION

Uytenbogaardt: Do you have any information about the absolute age determinations of the different uranium deposits?

Mittempergher: Yes, we have some age determinations of uranium in sedimentary deposits connected with the Upper Permian sandstones. The maximum age we found is 220 million years. In the case of syn-metamorphic regeneration of uranium deposits we have a clear younger age. Still in one case we found, if I well remember, about 90 million years.

Petrascheck: I may make a few remarks concerning the numerous new finding of uranium in the Austrian Permo-Triassic beds. I got the impression that your paleogeographical approach is the right one I think in the Austrian Alps even a more detailed paleogeographic conception would be possible separating the different Alpine troughs and uplifts as the so-called "unterostalpine Zentraltrias" and "mittelostalpine Zentraltrias", all of them containing in several places uranium. As far as it concerns the connection with the Permian volcanism, it is probable. It is true that even in the metamorphic Permo-Triassic rocks we have clear evidences of Permian volcanism. But on the other hand — and Mr. Schulz may correct me — it seems that the uranium findings in the

Buntsandstein near Kitzbühel and in other places of the Werfen shale and Buntsandstein are not at all connected with volcanic phenomena. So I got the impression that the paleogeography is even more important than the volcanic activity, but as in many cases it may be the one and the other. I was very interested in this lecture you gave.

Mittempergher: Thank you very much, Professor Petrascheck. I quite agree with you that paleogeography is the most important condition for the uranium ore genesis in the Alpine Range. The lithological connection between uranium mineralizations and volcanic rocks of late Paleozoic is a conclusion of statistical calculations. I know very well the case of Kitzbühel connected with the Buntsandstein, where there are no volcanic rocks. Also in other parts there are no volcanic rocks. But by plotting all the mineral deposits, the connection between the volcanic rocks and the mineralization in the sandstone becomes very clear. I don't believe also that in the Žirovski Vrh uranium deposit there is a close connection between the mineralization in sandstones and the volcanic rocks.