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Autor(en): **Burkhard, D.J.M. / Rybach, L. / Bächtiger, K.**

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## **Uranium and copper ore minerals in a Lower Permian lapilli-agglomerate tuff in Eastern Switzerland (Weisstannental, Kanton St. Gallen)\***

by *D. J. M. Burkhard*<sup>1</sup>, *L. Rybach*<sup>2</sup> and *K. Bächtiger*<sup>3</sup>

### **Abstract**

A Permian uranium-copper occurrence in the Verrucano of the eastern Helvetic zone of the Swiss Alps has been studied with regard to its genesis. The host rock was deposited as a pyroclastite (lapilli-tuff breccia or agglomerate) in an aqueous environment. Essentially two rock components could be determined by microscopical and geochemical analyses, a dacitic-rhyodacitic and an andesitic-basaltic one. The Alpine orogeny caused metamorphism (zeolite facies) and an intensive stretching and shearing of the whole Verrucano sequence.

The uranium minerals are pitchblende, brannerite and pyrochlore-microlite and, secondary, meta-autunite II, uranophane and vandendriesscheite. Copper minerals are mainly chalcopyrite and malachite with brochantite. The uranium is of volcanic origin. It is present in both rock components but predominant in the dacites. The obvious connection with continental Permian volcanism is analogous to uranium occurrences in the Tertiary calc-alkaline volcanics of the Latin-American Cordilleras. The main U concentration, probably activated by Permian to Triassic hydrothermal waters, is located along pathways of higher permeability, i. e., the coarser grained pyroclastite.

*Keywords:* Uranium minerals, Permian pyroclastite, Eastern Switzerland.

### **I. Introduction**

Some copper and uranium occurrences in the eastern Helvetic zone of the Swiss Alps have been known and partly already described (AMSTUTZ, 1950, 1954), especially those of the "Mürtschenalp" (BÄCHTIGER, 1960, 1963, 1974). In the course of a subsequent prospecting program several further radiometric

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<sup>1</sup> Mineralogisch-petrographisches Institut, Universität Heidelberg, D-6900 Heidelberg.

<sup>2</sup> Institut für Geophysik, ETH-Hönggerberg, CH-8093 Zürich.

<sup>3</sup> Institut für Kristallographie und Petrographie, ETH-Zentrum, CH-8092 Zürich.

\* Contribution no. 511, Institute of Geophysics ETH Zürich.

anomalies have been discovered, like those of the Weisstannental with gamma radiation intensities up to 3 mr/h (RYBACH and AEBERLI, 1974). However, the genesis of all these occurrences has always been a matter of discussion. The present detailed petrographical and geochemical studies in the Weisstannental yield a key for the explanation of uranium occurrences in the Helvetic zone; furthermore, the results may contribute to the general understanding of the origin of uranium in young Paleozoic sediments of the Alps.

## II. Geological Situation

The locality "Oberer Plattnerboden"<sup>4</sup> in the Weisstannental (Fig. 1) with the main U mineral occurrences is situated at an altitude of about 2000 m in the St. Galler Oberland, between the Walensee and the City of Chur.

The Verrucano of the St. Galler Oberland and the Kanton Glarus is made up of a Permian, and partly also Upper Carboniferous, continental clastic sequence, generally consisting of greenish-grey, violet or dark-red conglomerates of diverse igneous, volcanic and/or sedimentary material, sandstones, siltstones and slates (TRÜMPY, 1960, 1966; FISCH, 1961). The deposition is likely to have taken place in a SW/NE oriented trough with an area of about 25–30 × 60 km. The trough axis shows a significant deviation from the general Alpine strike of WSW-ENE. The crystalline components are assumed to be erosion products from the neighbouring Hercynian massives, the northwestern Aar massive and the southeastern Gotthard massive (OBERHOLZER, 1933). The Lower Permian volcanism within the trough led to intercalations and separate formations of volcanics. During the Alpine orogeny the Verrucano and overlying Mesozoic sediments have been thrust towards the N upon Upper Cretaceous and Tertiary flysch as a part of the Helvetic nappes.

Most of the occurrences are situated about 50 m above this main thrust, the so-called "Glarner Hauptüberschiebung".

## III. Field Observations

The basis of the Verrucano in the region "Oberer Plattnerboden" consists of an agglomerate of lapilli tuff—a fact, which has not yet been recognized up to now—as described in section IV. In a fine grained slaty green-violet groundmass, pebbles with different diameters (2–30 cm) can be found. In a 10 m profile across the uranium bearing horizon, the lower part contains rather small pebbles within a groundmass with angular fragments whereas in the upper part within a coarse slaty groundmass less but larger pebbles are predominant.

<sup>4</sup> Locality names according to the Swiss Topographic Map (Landeskarte der Schweiz) 1:25000 sheet 1174 Elm, 1965; or 1:50000 sheet 247 Sardona, 1973.

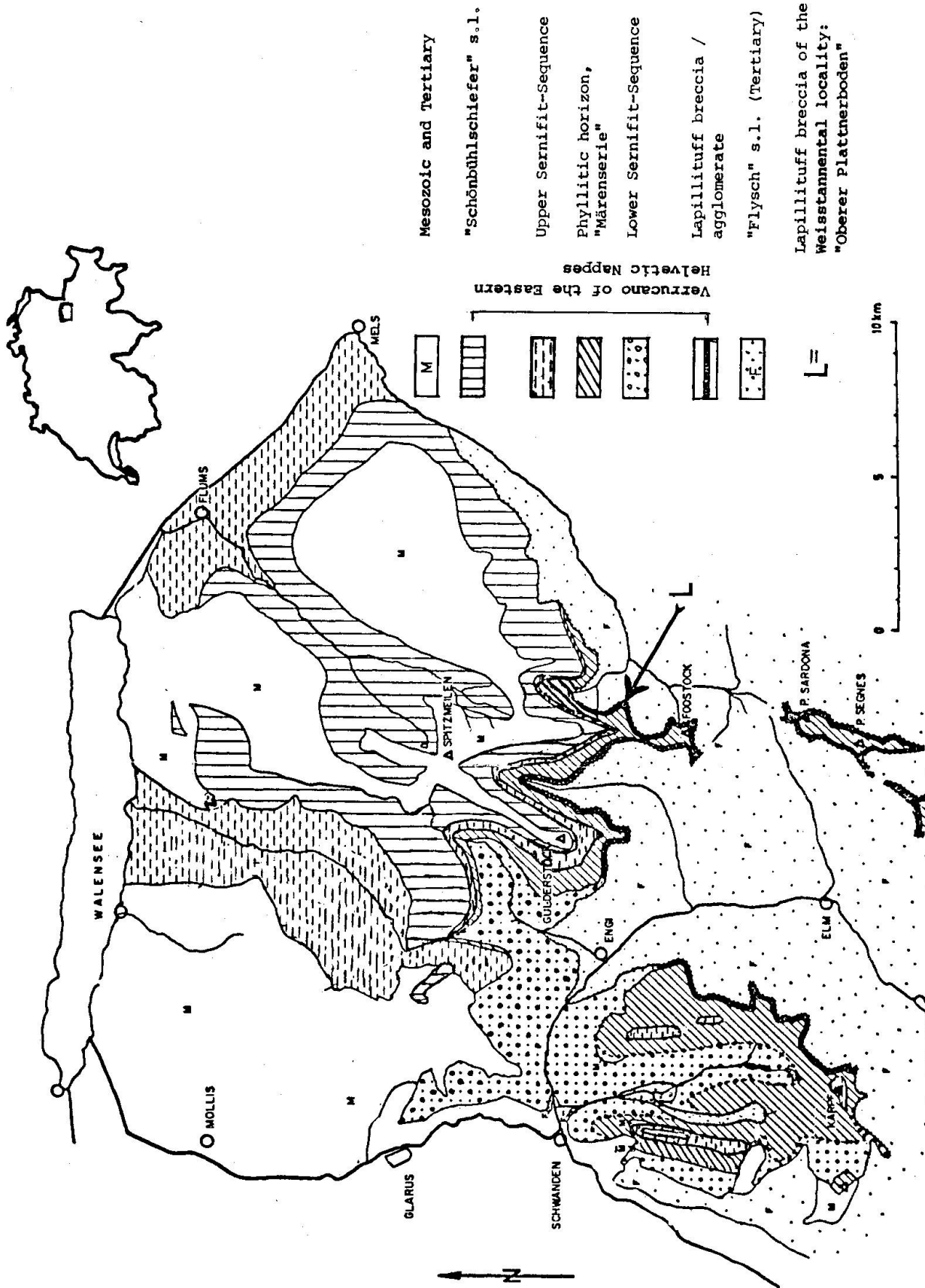


Fig. 1 Generalized geologic map of the Verrucano formation in the Kanton Glarus and St. Gallen, Switzerland (modified after Fisch, 1961) with the location of the investigated ore mineral occurrences (O.P. = Oberer Plattnerboden).



Above the uraniferous horizon, the upper part of the Verrucano becomes continuously finer grained, to reach finally a phyllitic appearance ("Märenserie").

Radiometric anomalies occur mainly in the upper 5 m of the lapilli-tuff horizon. All occurrences are clustered and isolated. The most important anomalies are located at the "Oberer Plattnerboden" in the upper part of the profile. They have been found during a prospecting program of the Swiss Federal Office of Science and Research (Bern)<sup>5</sup>. Intensities of up to 15000 cps could be measured with a portable SRAT scintillometer (about 3 mr/h). Only secondary uranium minerals, present as yellowish green coatings, can be macroscopically observed in the field. Much more abundant and striking are the green incrustations of malachite and brochantite.

A characteristic rusty-brown coloring, due to fine limonite films combined with yellow-orange oxidation products, usually point to the anomalies. At denser clustering of the anomalies, their radioactive intensity is usually also higher. Based on numerous gamma-spectrometric U determinations on rock samples (RYBACH and AEBERLI, 1974), an average U content of about 1000 ppm can be assumed for the "Oberer Plattnerboden" occurrence; this portion of the mineralization may contain 5-15 tons of uranium, depending upon the not well defined extension of the U-zone. U and Th contents of some samples from this horizon, analysed by the first author, are given in Tab. 1.

Table 1 Uranium and thorium contents (Gamma spectrometric determinations). For sample location see Appendix.

Sample	C <sub>U</sub> (ppm)	C <sub>Th</sub> (ppm)
U15	5 234 ± 2.8	543 ± 24
I11	245 ± 4.0	28 ± 4
II4b	98 ± 2.9	9 ± 4
V23	7 ± 0.5	1 ± 1
M23	9 ± 0.6	15 ± 1.3
H111	7 ± 0.3	6 ± 0.7
H173	4 ± 0.3	1 ± 0.7
H30	115 ± 0.6	17 ± 0.8

<sup>5</sup> carried out by the "Arbeitsausschuss für die Untersuchung schweizerischer Mineralien und Gesteine auf Atombrennstoffe und seltene Elemente".

#### IV. The Host Rock

The mineralogy of the agglomerate is rather simple and consists of chlorite, pale-mica (partly sericite), quartz, albite (with a few inclusions of epidote), and only one sample out of 100 shows calcite. The macroscopic and microscopic boundaries of the pebbles, which in some cases separate out readily, in other cases cluster together, are often not identical. The microscopic groundmass consists of micro- to cryptocrystalline albite and quartz (microprobe analysis) alternating with sericite and chlorite patches. Within this groundmass only albite may occur as phenocrysts<sup>6</sup>, in different sizes and densities of distribution, twinned and untwinned. The twinning is according to the Albite and Carlsbad Law; the untwinned albites may have inclusions of epidote, and very scarcely a distinct zoning could be recognized. Two main groups can be distinguished:

- "A" consists of a microfelsitic groundmass, with albite phenocrysts, twinned according to the Carlsbad Law up to a grain size of 5 mm. The shape of some untwinned albites with a size of about 0.5 mm is similar to the typical sanidine shape; so, these albites might represent altered sanidine. A few samples show quartz phenocrysts and thus represent a more siliceous component. Component "A" corresponds to photograph 1.

- "B" is characterized by albites which appear often as laths, smaller than 1 mm in length. With a relatively high distribution density they approach a poikilitic texture. Patches of regular crystallographic outlines are mostly filled with chlorite. In one sample interstitial calcite could be observed. Component "B" corresponds to photograph 2.

The host rock turns out to be a pyroclastite; the described textures are typical for volcanics. They correspond to the description of "spilites and keratophyres" in the neighbouring area of Glarus (AMSTUTZ, 1950, 1954, 1968; AMSTUTZ and PATWARDUHAHN, 1974; BÄCHTIGER, 1960, 1963; FISCH, 1961; MAYER, 1982), for which more recently the term "albite basalt" is used (ZHANG et al., 1981). "B" shows the same texture as it is observed in andesites and basalts, while the texture of "A" is similar to that of a dacite, or a rhyodacite, if there are quartz phenocrysts.

#### X-RAY FLUORESCENCE ANALYSES

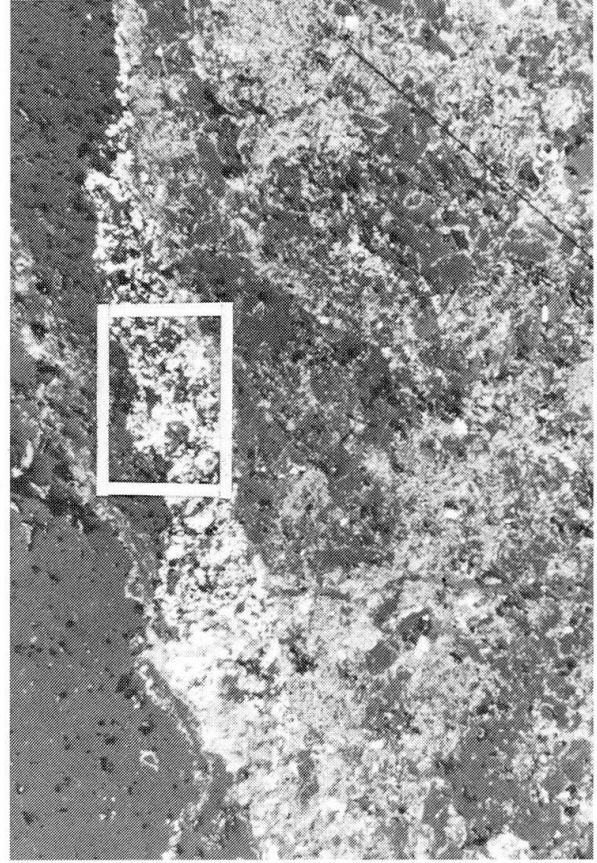
The major and the trace elements of eight samples have been analyzed by X-ray fluorescence and, for more precise U and Th values, also by gamma-spectroscopy (Tab. 1, 2, 3).

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<sup>6</sup> Microprobe analyses of different albite occurrences showed no significant variation in their chemistry.



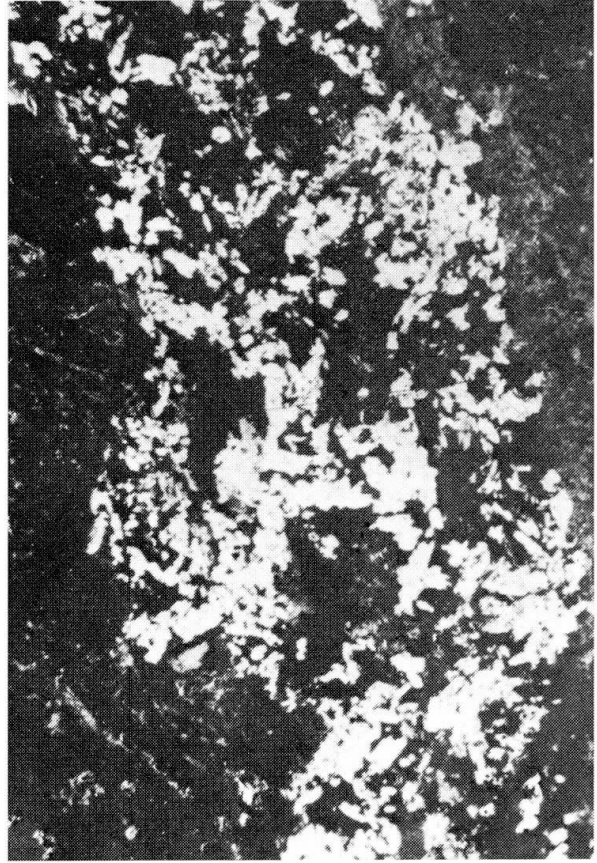
Photograph 2 (width: 3.3 mm). Andesitic rock component with albite laths.



Photograph 4. Enlarged portion of photograph 3 showing the fine brannerite needles.



Photograph 1 (width: 3.3 mm). Dacitic rock component, sheared during Alpine deformation, with primary uranium minerals (lower part of photograph).



Photograph 3 (width: 1.0 mm). Brannerite (light band in upper part of photograph) and pitchblende in a fine network Area of photograph 4 is marked as a white square.

U 15, I 11 and II 4b are taken from the uranium bearing horizon; U 15 is typical for the U bearing samples (ca. 0.3 mr/h), I 11 is characterized by a cover of meta-autunite II and by a small amount of malachite. V 2c originates from below, and M 23 from the phyllitic, fine-grained sequence above the horizon with U. H 111, H 113 and H 30 are darker and homogeneous single pebbles of the lower part of the U bearing horizon.

Referring to analyses given, for example, by EWARD (1979), one can state that U 15, II 14b and V 2c correspond to a dacitic composition, regarding the major elements, I 11 more closely resembles a rhyodacite (the highest  $\text{SiO}_2$  content), whereas H 111 and H 113 can be compared to an andesitic composition and H 30 is more or less basaltic. The only difference is due to the low Ca content; it corresponds to low-Ca plagioclase. The alkalis are quite similar to analyses presented by EWARD (1979). Also from this geochemical point of view the rock samples may be compared to "spilites", "keratophyres", and, in part "quartzkeratophyres".

The position of the rock analyses in the AFM diagram is shown in Fig. 2. The resulting two main groups correspond exactly to the microscopically observed groups "A" and "B"; I 11, U 15, II 14b and V 2c show the characteristic features of "A" and H 111, H 113 and H 30 those of group "B". Consequently group "A" can be referred to a dacite-rhyodacitic and group "B" to an andesite-basaltic component. The  $\text{Na}_2\text{O} + \text{K}_2\text{O}$  vs.  $\text{SiO}_2$  diagram illustrates again these two groups. The spatial position of the "Märenserie", the overlying phyllitic horizon, is evident. Especially in the  $\text{Na}_2\text{O}$  vs.  $\text{SiO}_2$  and in the  $\text{CaO}$  vs.  $\text{SiO}_2$  diagrams, the U bearing samples group together (Fig. 3).

Regarding the trace elements the high Cu content is striking, as also the higher Ba values; 200–300 ppm would have been expected. Worthwhile to mention are the Nb and Zr contents in U 15 (they may be present in some small, undetectable amounts of pyrochlore-microlite).

The Rb and Sr values are remarkable; the reverse proportions in the dacites and andesites compared to the basalts are striking. These ratios may reflect the different primary mineralogy; the earlier Ca-rich fractions (basalts) fix more Sr and consequently, the later crystallizing fractions (andesite, dacite, rhyodacite) contain the highest Rb/Sr ratios. Another reason for these ratios may be the different amounts of radiogenic Sr which would refer to different ages of these rock sequences (JÄGER, 1979). In any case, the remarkably high Rb and Sr values of all rock components may be interpreted as a hint to an originally higher Ca content of these rocks.

## V. The Ore Minerals

The main problem of these investigations was the very fine grain size of all ore minerals; their diameter was often less than 1 mm. The identity of some ura-



Table 2 Major elements: whole rock analyses, X-ray spectroscopy (for location of samples see Appendix).  
 The analytical error depends in the following way on the concentration:  
 concentration 50%:  $\pm 1-2\%$  5 %:  $\pm 3-4\%$  0.1%:  $\pm 8-12\%$   
 10%:  $\pm 2-3\%$  0.5%:  $\pm 5-8\%$

Wt. %	U15	I11	II46	V2C	M23	H111	H113	H30
Si O <sub>2</sub>	70.57	66.75	71.76	65.55	61.65	58.57	53.06	52.15
Ti O <sub>2</sub>	0.42	0.64	0.45	0.54	0.75	1.41	1.47	1.56
Al <sub>2</sub> O <sub>3</sub>	12.42	14.78	13.39	13.42	16.91	13.56	14.51	15.28
Fe O	1.06	2.82	1.43	1.82	2.52	4.38	5.52	3.36
Fe <sub>2</sub> O <sub>3</sub>	1.62	1.47	1.17	2.24	3.74	6.80	8.72	11.30
Mn O	0.3	0.11	0.10	0.10	0.04	0.17	0.15	0.23
Mg O	0.9	2.54	1.31	1.44	1.80	3.38	4.16	3.01
Ca O	0.18	0.26	0.54	1.51	0.26	0.94	0.88	4.74
Na <sub>2</sub> O	3.89	4.00	3.95	3.54	3.64	4.20	3.89	4.89
K <sub>2</sub> O	1.08	1.67	1.43	1.79	2.82	0.24	0.38	0.39
P 2O <sub>5</sub>	0.11	0.16	0.10	0.14	0.18	0.35	0.28	0.28
Cr <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
C O <sub>2</sub>	0.35	0.07	0.33	1.01	0.05	0.30	0.34	2.54
H <sub>2</sub> O	2.08	1.04	2.47	1.78	2.27	4.55	4.25	4.80
Total	94.98	96.32	98.43	94.88	96.63	98.85	97.61	100.44

Table 3 Trace elements (for location of samples see Appendix) analytical error: 3-15%.

ppm	U15	I11	II4b	V2c	M23	H111	H113	H30
Nb	162	-	-	-	-	-	-	-
Zr	431	195	149	171	262	147	43	99
Y	-	15	25	19	37	27	14	28
Sr	13	34	35	43	35	88	119	194
U	5714	158	136	-	-	-	-	-
Rb	129	52	48	57	111	4	10	18
Th	-	-	-	-	-	-	-	5
Pb	242	-	1	-	-	-	116	45
Ga	1	7	4	7	14	9	14	15
Zn	82	149	62	43	88	165	235	172
Cu	5112	2258	1578	103	201	49	2374	1391
Ni	3	22	3	4	27	10	15	21
CO	2	12	-	3	12	19	21	20
Cr	10	29	4	13	52	16	8	13
V	223	340	109	137	183	37	210	262
Ce	62	68	27	51	72	72	6	21
Nd	27	21	13	28	34	44	-	2
Ba	187	97	249	425	691	73	1277	336
La	-	23	4	12	36	20	-	-
SC	26	21	15	18	22	25	47	48
S	432	67	16	-	-	-	415	386
Total	12858	4440	2726	1134	1878	802	4973	3076

nium-free minerals has been verified with Energy Dispersive Microprobe analyses (EDS).

The following ore minerals have been recognized:

#### A. URANIUM-BEARING MINERALS

The reduced uranium minerals are, in the probable order of their formation: pyrochlore-microlite, pitchblende, brannerite. The secondary alteration products include the following: meta-autunite II,  $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_3 \cdot 0-2 \text{H}_2\text{O}$  (ASTM); uranophane,  $\text{Ca}(\text{UO}_2)_2\text{Si}_2\text{O}_7 \cdot 6 \text{H}_2\text{O}$  (ASTM); vandendriesscheite,  $8[\text{UO}_2/(\text{OH}_2)]\text{Pb}(\text{OH})_2 \cdot 4\text{H}_2\text{O}$ ; and a mineral similar to marthozite,  $\text{Cu}(\text{UO}_2)_3(\text{SeO}_3)_2(\text{OH})_2 \cdot 7 \text{H}_2\text{O}$ .

#### B. URANIUM-FREE MINERALS, INCLUDING COPPER MINERALS

We could identify: hematite, ilmenite, magnetite, pyrite, chalcopyrite, tetrahedrite, bornite, galena, chalcocite, covellite, and, as oxidation products, Fe-hydroxides, rutile, anatase, pseudobrookite, malachite, brochantite and scarcely cuprite.

#### INDIVIDUAL DESCRIPTIONS

*Pyrochlore-microlite* was found very scarcely with a dark brown to reddish color. The identification was possible only by the Gandolfi camera. This mineral may correspond to the high Nb and Zr content of sample U 15; it is a

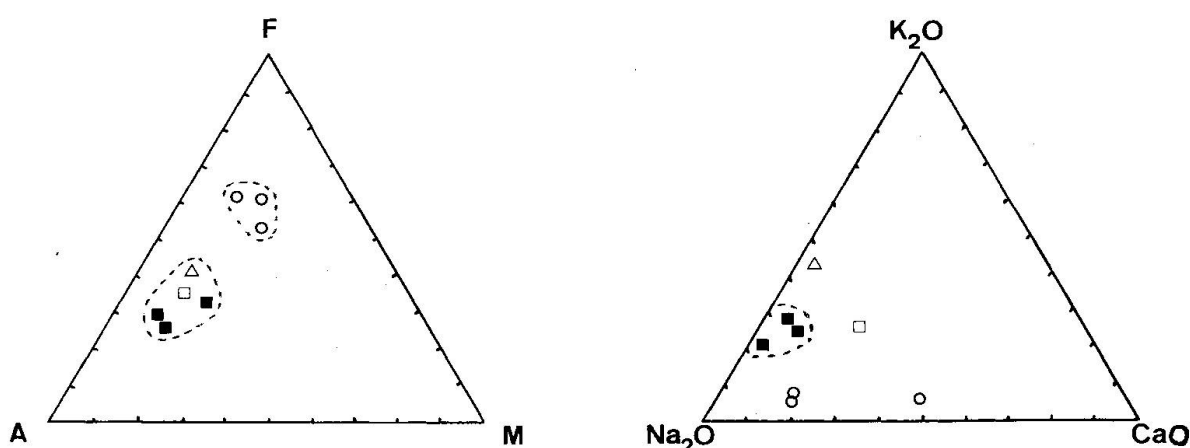


Fig. 2 Variation diagrams (bulk chemistry) of the samples from "Oberer Plattnerboden", Valley of Weisstannen. Dark squares: samples from the horizon with ore minerals (cf. Appendix); open square: sample from below the horizon with ore minerals; triangle: sample from the overlying phyllitic "Mären-Serie"; open circles: single pebble components from below the horizon with ore minerals.

A:  $\text{Na}_2\text{O} + \text{K}_2\text{O}$ , F:  $\text{FeO} + \text{Fe}_2\text{O}_3$ , M:  $\text{MgO}$

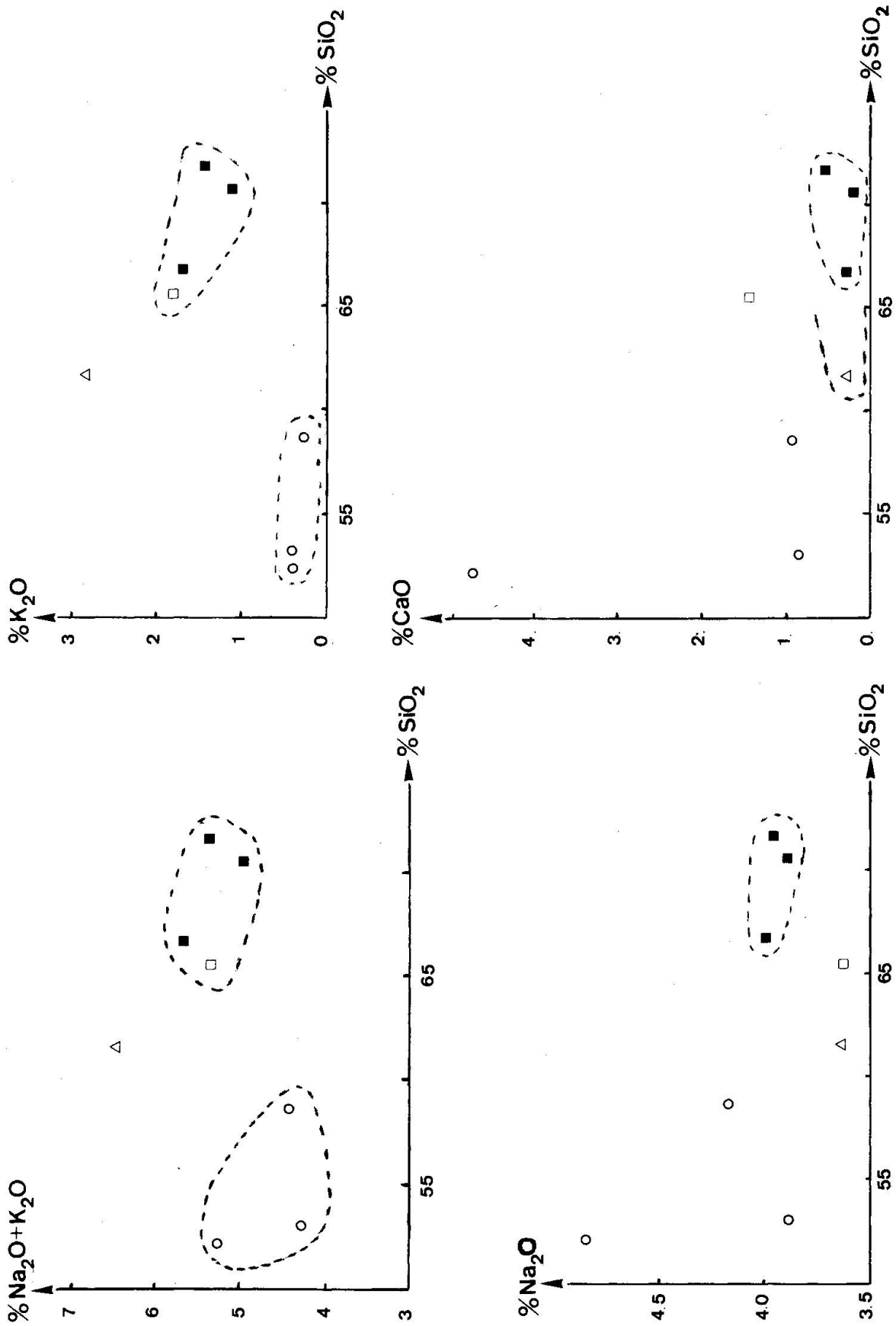


Fig. 3 Explanation see text and Fig. 2.



typical primary U mineral, normally found in alkaline rocks,  $(\text{Na,Ca,U})_2(\text{Nb,Ti,Ta})_2\text{O}_6(\text{OH,F,O})$ .

*Pitchblende* appears normally anhedral in networks, finely twisted with the host rock and only scarcely in massive structures (photograph 3). This feature points to an early formation of this mineral, more or less contemporaneous with the formation of the surrounding silicate minerals. The pitchblende may occur together with pyrite and rarely also with chalcopyrite. Eight microprobe analyses showed a partially high  $\text{SiO}_2$  content ranging from 1–15%, and a proportional content of  $\text{Al}_2\text{O}_3$ , from 0.15% up to 7%; this may reflect a very fine intergrowth with the silicates.  $\text{PbO}_2$ ,  $\text{ThO}_2$ ,  $\text{BaO}$  and  $\text{P}_2\text{O}_5$  could not be detected. The d-values (X-ray determination) can well be correlated with the values given by FRONDEL (1958) which leads to an  $a_0$  of 5.46 Å. The  $a_0$ -values are a complicated function of the substituted elements according to CATHELINÉAU et al. (1982).

*Brannerite* shows the typical small needles (photograph 3 and 4). But it was too fine-grained for a separation under the binocular for Gandolfi camera measurements. As to its formation, there are generally two possibilities: first, by the so-called "Prontoreaction" (RAMDOHR, 1957), secondly as weathering products of ilmenite; during this decomposition process uranium can enter the structure of the secondary Ti minerals from circulating solutions. The presence of pitchblende, together with brannerite, can be explained as formation of free  $\text{UO}_2$ , amorphous (or even crystalline), only after saturation of all Ti complexes within the host rock (RAMDOHR, 1957; BÄCHTIGER, 1963). Only rock parts with high U concentrations show generally abundant pitchblende, besides brannerite; but we have to note that pitchblende contains small amounts of Ti, Al and Mg.

19 microprobe analyses have been carried out; a partly high  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  content is not surprising regarding the very fine brannerite needles intergrown with the silicates.  $\text{BaO}$  ranges from 0.15% to 1%,  $\text{MgO}$  from 0.1% to 0.5%. Small amounts of ThO could be determined in two samples.

*Meta-autunite II* occurs in most cases as bright yellow-greenish rock coatings and more rarely as light greenish, very finely radiating crystals. The identification was only possible by the Gandolfi camera.

*Uranophane* is present in a form similar to the finely radiating crystals of meta-autunite II, but with a yellow to white color. The analyses by electron microprobe yield the following molecular formula:  $\text{Ca}(\text{U}_{1.7-2.0}\text{Pb}_{0.3-0.0})\text{O}_4\text{Si}_2\text{O}_7 \cdot 6\text{H}_2\text{O}$ .

*Vandendriesscheite* has a lemon-yellow to golden-yellow to orange color and is either glassy or forms rosettes. Quantitative analyses were not possible for various reasons. However, a  $\text{BaO}$  content of up to 10 wt.% could be estimated.

It is worthwhile to mention that brochantite (checked by EDS) may have a uranium content up to several percent; also there are some orange-brown co-

lored concretions that consist of albite and contain significant amounts of U, Pb and Cu in an unknown chemical composition (determinations also by EDS).

Meta-autunite II, uranophane and vandendriesscheite are typical weathering products of the oxidation zone. Uranophane and vandendriesscheite may occur within goethite: the capacity of ferrihydroxide gels to absorb U is reduced during the aging process; consequently the once absorbed U will form secondary U minerals occurring as inclusions in these ferri-hydroxides (DYBECK, 1968). The meta-autunite II may have a more complex history; at first, under normal P-T conditions, the "original" autunite was probably formed as weathering product. It may have been transformed reversible into meta-autunite I as a function of T and  $P_{H_2O}$ . At a temperature of at least 75 °C, meta-autunite II is formed as an irreversible dehydration product (FRONDEL, 1958). This event has most probably taken place at the end of the regional metamorphism.

## VI. Genetic Considerations and Discussion

### THE HOST ROCK

As already mentioned above, the host rock contains two main components, and, in general, the host rock can be compared to an altered dacite. Regarding the high Nb and Zr content of sample U 15, as well as the occurrence of pyrochlore-microlite, the possibility of an alkaline trend for the origin and genesis of the host rock has to be considered. This seems to be supported by a comparison with rock analyses given for example by BOWDEN (1974) and also by SMELLIE et al. (1984). A high U content of some alkaline rocks is also known (SEME-NOV, 1974), but it occurs in more acid rock types. Further, the occurrences at Skuppersavon, N-Sweden (SMELLIE et al., 1984) show a similar chemistry to the rocks discussed here, but there the U has been introduced secondarily by hydrothermal solutions.

However, the different microscopical textures which are characteristic for dacites, andesites and basalts, combined with the results of the whole rock analyses, which yield a rather wide chemical spectrum, point much more to a continental calc-alkaline suite, even if a certain alkaline influence can not be ruled out.

It is still debated whether this typical mineral paragenesis and especially the albites (phenocrysts and matrix) could be primary magmatic or if they are secondary, i. e., an alteration product of a low grade metamorphism. The high Rb and Sr values seem to advocate for a secondary formation; the whereabouts of the Ca is a problem. An extensive discussion of the "pros and cons" is published in the "Spilite Volume" (AMSTUTZ, 1974).

The deposition of the lapilli-agglomerate may have taken place within water as indicated by a large variation of the pebble shape, angular to well rounded,

together with well sorted tuff lenses and layers. The later Alpine metamorphism has been very weak.

#### THE U MINERALIZATION

Analyses, carried out with the more sensitive gamma-spectroscopy, compared to the X-ray fluorescence, proved U in all samples investigated; U is not exclusively bound to the acid component as one would expect; instead, the U is most abundant in the intermediate components and occurs in remarkable amounts in the basics.

The well-known fact that effusives have a principally higher U content than the corresponding intrusives (MALAN, 1972) is generally explained as follows: the greater part of the uranium in the effusives was fixed and conserved within the glass matrix during their fast solidification, whereas the intrusives have lost important quantities owing to their slower crystallization (DYBECK, 1962; HARRIS et al., 1970; MICHAEL and SCHNEIDER, 1978).

However, the uranium values of the pyroclastite components of the "Oberer Plattnerboden" are significantly higher than usual for comparable effusives (MALAN, 1972); this is the case especially for the U content of sample H 30. This observation is similar to that which MICHAEL and SCHNEIDER (1978) describe from the Tertiary volcanics of the South American Cordilleras.

Important processes for the later U concentration may have been devitrification, diagenesis, and, in part, metamorphism. The U which will be released during devitrification and might be transported by carbonate complexes (SMITH and ZIELINSKI, 1979; BLOCH and KENNETH-JOHNSON, 1980); DeVoto (1978) emphasizes the importance of early diagenetic waters.

A hydrothermal activity from the Permian up to the Upper Triassic in corresponding sequences nearby the Weisstannental has been proved (BÄCHTIGER, 1974). So, hydrothermal waters may have been responsible for a partial redistribution and concentration of the uranium, as some veinlet fillings with pitchblende and brannerite suggest. For the transportation paths rocks of higher permeability are the logical place, as for example the coarser grained lapilli-tuff agglomerate, compared to the overlying phyllitic tuffite (Märenserie). The precipitation, preceded by the reduction  $U^{6+} \rightarrow U^{4+}$ , was mainly caused by the change of the permeability at the boundary to the Märenserie.

No observations could be made which would point to the formation of "rolls" neither macroscopically nor microscopically. The U-occurrences described in this paper are hard to place in one of the available standard classifications. Perhaps they are best described as a combination of DAHLKAMP'S "Sedimentary Group" (DAHLKAMP, 1978) with the significant difference that the U pertains to the volcanic material, i. e., not only to the acidic but also to the intermediate and basic components.

Several other U occurrences are known in the Helvetic Verrucano of Eastern Switzerland. The most important U and Cu occurrence is that of the Mürtschenalp, west of the Weisstannental. Here the U and Cu have been concentrated in Postvariscan and Prealpine fracture zones by Upper Triassic hydrothermal activity (BÄCHTIGER, 1963, 1974). Another example are the U occurrences in feldspar-muscovite schists in the Vorderrheintal, near Truns, south of the Weisstannental (KRAMERS, 1972). From this locality detailed analyses are available. Distinct radioactive anomalies could be proved in the Kanton Glarus, at a location named Sunnehörnli (RYBACH and AEBERLI, 1974; BURKHARD, 1982) and in the Glarner Freiberg (AMSTUTZ, 1954); they occur with acid volcanics and Verrucano breccias, like in the Vorderrheintal near Truns (BURKHARD and GRELLER, 1983).

#### COMPARISON WITH OTHER URANIUM OCCURRENCES

Numerous U occurrences are known in Europe which are connected with a Permo-Carboniferous up to Triassic volcanic activity. Especially the occurrences in the Southern Alps may be compared with the occurrence of the Weisstannental. The U occurs in acid volcanics, ignimbrites and acid tuffs and is considered to be of hydrothermal origin, as for example in Novazza, Italy (MITTEMPERGER, 1966, 1970). The occurrences in the W-Carpathians may be similar (RUZICKA, 1971). In Valganna (Varese, I), U has been prospected in a pyroclastic part of a basal tuff sequence and is accompanied by Ti, V and P enrichments. An Alpine age is assumed. Regarding the genesis, MITTEMPERGER, (1970) suggests a connection with H<sub>2</sub>S; for FRENZEL et al. (1975) meteoric waters are most likely responsible for the formation.

#### VII. Conclusions

Microscopical investigations of an uranium-bearing agglomerate of the lower Verrucano sequence at the base of the Helvetic nappes (Weisstannental, Oberer Plattnerboden) shows that it consists of two main rock components. Texturally and compositionally they are similar to (rhyo)dacite and to andesite-basalt. The rock as a whole may be defined as a lapilli-tuff agglomerate. The primary minerals are altered to albite, quartz, chlorite, and pale-mica.

The dacitic components are more abundant and they contain most of the uranium. However, an abnormally high U content could also be proved by gamma spectroscopy in the andesitic component and in one basaltic pebble.

Various processes, such as devitrification, diagenesis and hydrothermal water circulation may have caused concentration and remobilisation of U. Trans-

port and precipitation along channels of high permeability led to a final concentration of U minerals in the pyroclastite horizon underneath the less permeable tuff to tuffitic horizon. The influence of the only weak Alpine metamorphism is difficult to estimate; it may have been responsible for the formation of the various secondary U minerals.

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## APPENDIX

### Location of the investigated samples (within a profile at "Oberer Plattnerboden")

- from the phyllitic, fine-grained "Mären-Serie" above the uranium-bearing horizon: M 23
- from the uranium-bearing horizon: U 15, I 11, II 4b
- rock pebbles from below the mineralized horizon: H 111, H 113, H 30
- from below the mineralized horizon: V 2c
- pebbles from the conglomerate below the U-bearing horizon: H 111, H 113, H 30
- from below the U-bearing horizon: V 2c

### Bulk chemistry

- dacitic: U 15, II 4b, V 2c
- rhyodacitic: I 11
- andesitic: H 111, H 113, M 23
- basaltic: H 30