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ACID IGNEOUS ROCKS OF THE STAVELOT MASSIF, A CASE OF PRE-HERCYNIAN WEATHERING.

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ABSTRACT. - Acid intrusive and extrusive rocks of the Stavelot Massif (Belgium) have been analyzed for major- and trace elements. The extrusive rocks have been subjected to pre- or syndiagenetic weathering, during which process biotite was a stable mineral. The acid rocks are considered to be cogenetic on the basis of their Ti-Zr-Rb ratios.

INTRODUCTION.

Conformable bodies of felsitic igneous rocks, associated with cambrian and ordovician sediments, occur throughout the Stavelot Massif. When first recognized they were collectively described as "eurites" or keratophyres (Dumont, 1847; de la Vallée Poussin & Renard, 1876).

An extensive review of all known occurrences, their chemistry, and their petrography was published by Corin (1965); of those, the localities in the caledonian Stavelot Massif were visited and sampled in so far as they were still accessible and not too badly weathered. Several newly found localities were also investigated (see Fig. 1). The "eurites" are pre-devonian in age (Geukens, 1969, 1976). The objective was to establish their nature (sill, dike, flow or tuff) by petrographic analysis; and their chemical identity as a group by trace element analysis.

Six conformable bodies at Spa, Targnon, Coe, Francorchamps, Bra and Trois Ponts, and two dikes at Spa were sampled. Two samples of the tonalitic intrusives at Lammersdorf and La Helle were added for comparison.

PETROLOGY.

The five conformable bodies at Targnon, Bra, Coe, Francorchamps and Trois Ponts, each occur as a single layer of up to a few meters in thickness, between revinian quartzites and phyllites (samples 1 to 5). They are rhyolitic in composition and have a matrix consisting of a finegrained mixture of quartz, chlorite and sericite. In this matrix, only phenocrysts of quartz, strongly chlorotized bio-

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tite and sericitized albite are left. The material is very heterogeneous. The quartz phenocrysts are embayed and often occur in clusters. The nature of these conformable bodies is seen as volcanic rather than plutonic in view of the absence of a decrease in grain size towards the periphery. The presence of flattened matrix fragments (Ross and Smith, 1961), and smooth contacts with the wall rock in combination with their constant thickness, seems to indicate that they were tuffs rather than flows.

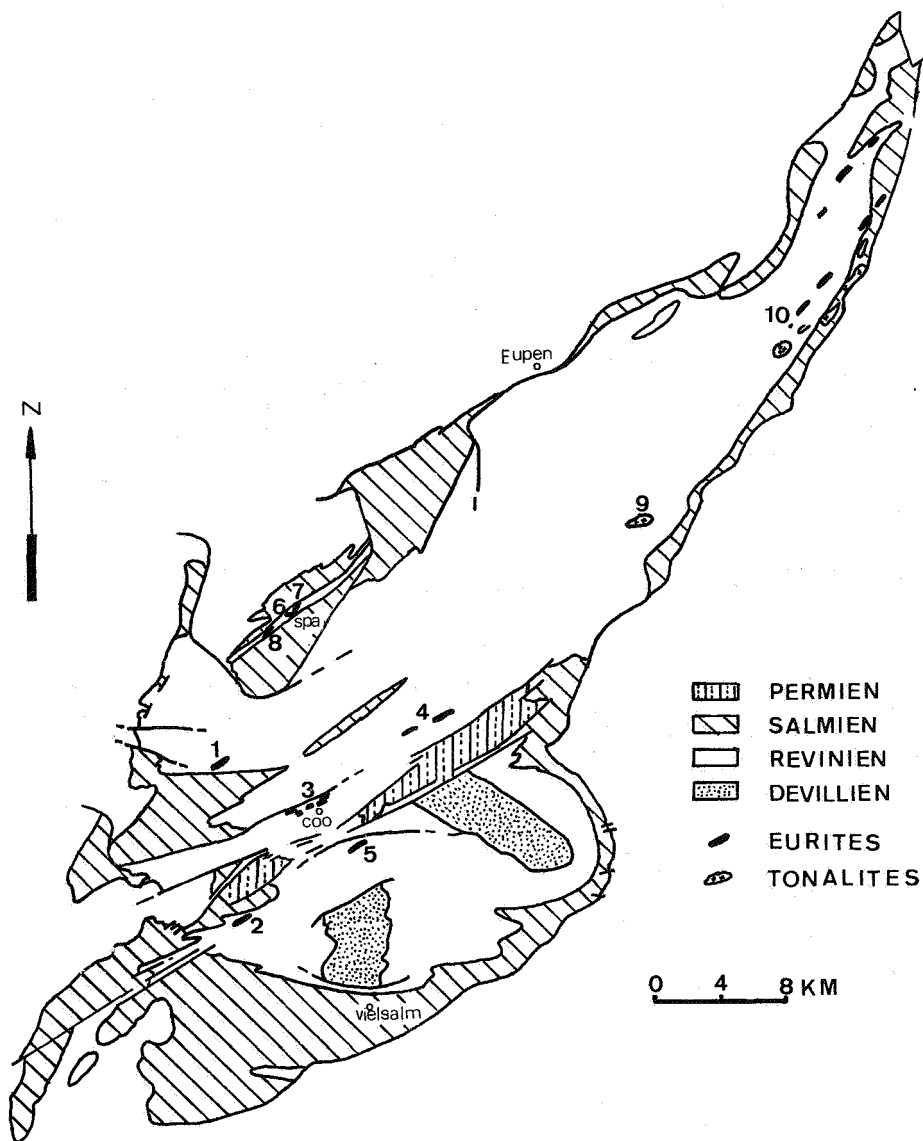


Fig. 1 Geological sketch map of the Stavelot Massif (after Corin, 1965) with the sampled localities of igneous rocks (numbers refer to Table 1).

Dikes crosscutting revinian strata were found at Spa (samples 7 and 8). They consist of soda rhyolite porphyry, with phenocrysts of non-embayed quartz, clear albite, chlorite and chloritized biotite in an aplitic matrix. The grain size of the matrix markedly decreases at the periphery of the dikes, where locally some xenoliths may be present. Although conformable in nature and lacking a chilled margin, the body described by Dumont (1847) as the left branch of one of the abovementioned dikes (city park at Spa, sample 6) is considered intrusive rather than extrusive in view of its petrographic resemblance to the dikes. It lacks the intensive alteration of the feldspars, has a rather low Niggli t-value, contains no embayed quartz, and shows the same aplitic matrix. Thus, petrographically, the acid igneous rocks could be subdivided into two groups; one of an intrusive, the other of an extrusive nature.

In all the "eurite" bodies, zircon and sphene are accessory constituents. Titanium oxides (rutile, etc.) were not observed and are not expected to be present on the basis of the magmatic affinity and the metamorphic state of the analyzed rocks.

The sphene is always associated with chlorite (secondary after biotite). Despite the use of staining techniques (Laduron, 1966) potash feldspar could not be found in any of the investigated specimens.

Samples 9 and 10, added for comparison, were taken of the tonalitic intrusives of La Helle and Lammersdorf respectively. A detailed study of these intrusives was published by Scherp (1960).

CHEMISTRY.

One sample from each of the localities was analyzed for major elements and selected trace elements (see Table 1). For the determination of SiO_2 and Al_2O_3 an argon plasma emission spectrograph was used; the remaining major elements, including Ba, and Mn were determined by atomic absorption spectrophotometry. FeO was determined by titration according to the method of Shafer (1966). Zr, Rb, Sr and duplicate Ti values were obtained by x-ray-fluorescence using the methods of Norrish and Hutton (1969) for Ti, and of Duchesne and Roelandts (1971) for Zr, Rb and Sr. Accuracies, calculated with the aid of standards, were: 3.3 % (Ti), 3.5 % (Zr), 5.5 % (Rb) and 14 % (Sr).

The two groups which could be defined within the "eurites" because of their petrographical and geological differences have chemical characteristics that seem to warrant this distinction. In a Niggli al against alk plot, the extrusive bodies are seen to be relatively poor in alkalis while the intrusive bodies have intermediate or relatively high values (Fig. 2A, inset).

In order to establish whether this concerns a fundamental difference in chemistry, the aluminum surplus (expressed as Niggli-t) and the total alkali content were plotted against the Weathering Potential Index (WPI; Reiche, 1943) in fig. 2A, where t shows a positive, and the alkalis a negative correlation with weathering. The high t-values in the extrusive bodies (38.6 - 46.3) are ascribed to weathering, possibly in conjunction with some hydrothermal leaching, since they fall outside the range for fresh acid volcanics (-5 to +3), anatectic acid magmas (+5 to +15) and show only a slight increase in the Niggli-k value which can be used as an indicator for hydrothermal leaching (Waldhausröva, 1971; Vogel, 1975). An increase in Zr-content (Fig. 2A) with weathering could likewise be expected if it is assumed that all available Zr enters into the mineral zircon, since the latter is extremely resistant to weathering (Ollier, 1969).

In order to be able to use trace elements for a chemical discrimination within the "eurite"-group according to the method

	1	2	3	4	5	6	7	8	9	10
sample locality	Targnon	Bra	Rau Moray Coo	Francor- champs	Trois- Ponts	Spa City-park	Spa City-park	Spa	La Helle	Lammers- dorf
a)										
wt.% SiO ₂	56.08	72.27	70.75	73.82	64.30	71.99	77.78	75.00	73.28	73.46
Al ₂ O ₃	21.67	16.73	15.24	14.43	20.17	15.60	12.15	13.45	13.64	13.42
Fe ₂ O ₃	0.18	0.17	0.18	0.11	0.39	0.08	0.41	0.17	1.16	0.15
FeO	6.13	2.01	3.67	3.14	2.02	2.12	0.74	1.76	1.71	1.85
MgO	2.57	0.66	1.00	0.79	0.44	0.77	0.34	0.59	0.88	0.98
CaO	0.19	0.27	0.41	0.29	0.16	0.23	0.16	0.10	2.08	2.41
Na ₂ O	1.24	1.05	0.98	1.05	1.09	6.00	2.75	3.26	3.50	3.44
K ₂ O	1.69	2.74	1.88	2.11	3.59	1.00	1.97	2.06	2.43	2.08
H ₂ O+	6.89	3.79	3.97	3.27	5.48	1.97	2.00	3.32	1.65	1.64
H ₂ O-										
TiO ₂	1.38	0.58	0.54	0.42	0.53	0.33	0.13	0.37	0.45	0.36
Total	98.02	100.27	98.62	99.43	98.17	100.09	98.43	100.08	100.78	99.79
b)										
ppm. Ti	8215	3853	3617	3081	3220	2365	1084	2218	2886	2358
Zr	536	365	272	299	331	208	126	249	127	249
Rb	299	541	249	335	592	119	291	219	283	289
Mn	308	45	133	49	26	163	37	n.d.	148	247
Sr	634	551	211	508	151	559	166	212	954	688
Ba	857	1362	975	2037	1312	500	537	n.d.	1825	1375

c)										
t	42.2	43.3	39.2	38.6	46.3	13.2	24.1	22.3	4.6	3.6
alk	9.3	17.6	13.2	15.7	18.5	34.1	30.8	29.8	26.2	25.4
al	52.3	62.7	55.1	56.4	65.8	48.6	56.3	52.8	42.6	43.2
k	0.47	0.63	0.56	0.56	0.68	0.10	0.32	0.29	0.31	0.28
WPI	-22.1	-10.0	-10.9	-8.2	-17.5	1.4	-2.3	-6.3	3.3	3.6
Na ₂ O+K ₂ O at. eq.	80	85	78	80	114	202	120	145	158	152

Table 1: Chemical analyses of acid magmatic rocks of the Stavelot Massif.

a) major elements; analyst D.Coetermans b) trace elements c) niggli values.

Analyses 1 through 6 represent conformable layers, 7 and 8 dikes, 9 and 10 larger intrusive bodies
locality mentioned by Corin (1965)

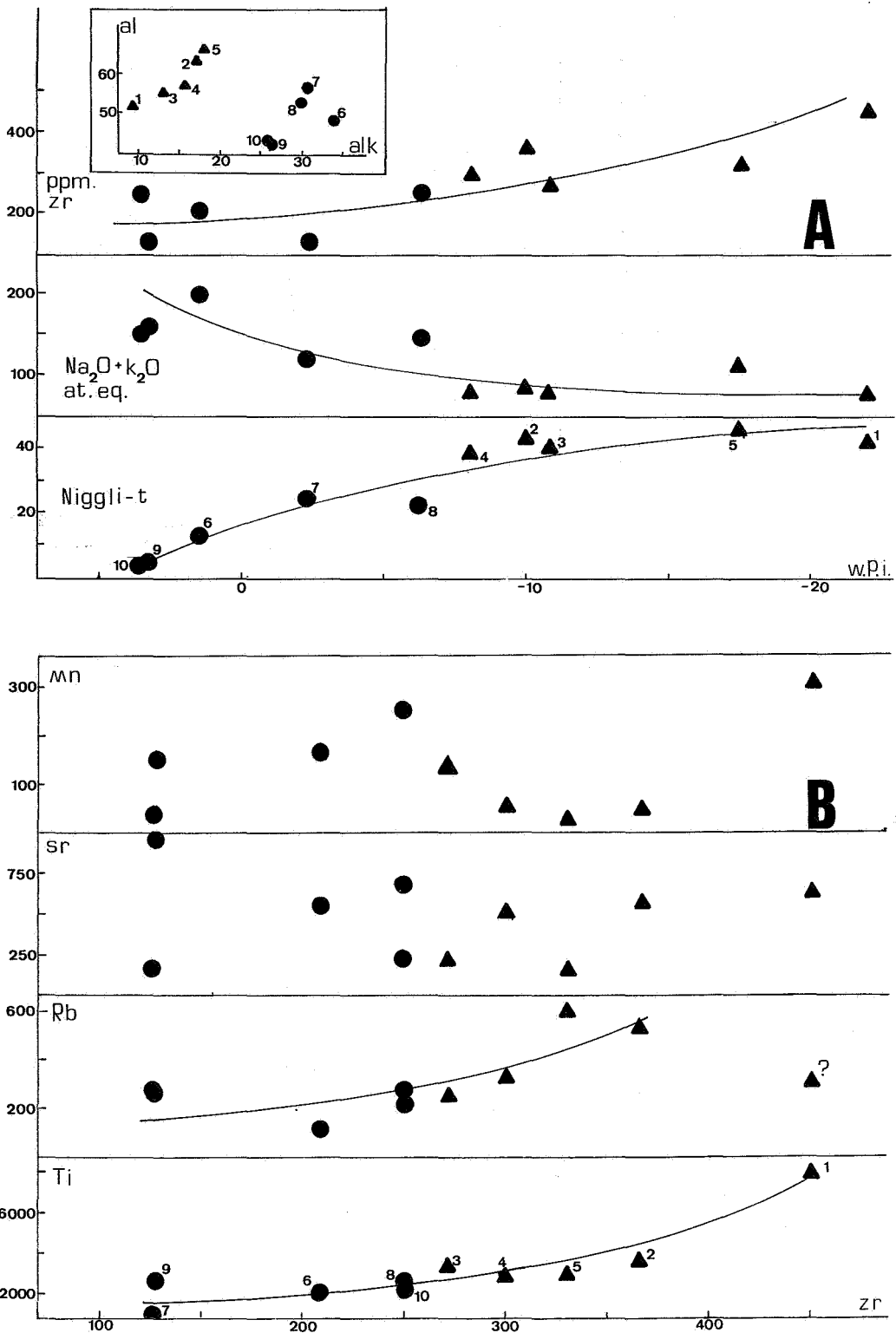


Fig. 2 A-B Plots of trace elements weathering potential index (W.P.I.), alkalis and Al-surplus (expressed as Niggli-t); numbers refer to Table 1.

used by Jack and Carmichael (1965), the effects of weathering upon the trace-element contents have to be discounted first. Using Zr as a reference for the degree of weathering, poorly defined negative correlations are obtained for Mn and Sr, and well-defined positive correlations for Rb and Ti (fig. 2B). The gradual disappearance of Sr with increasing Zr-content can be explained by the breakdown of feldspar upon weathering. The positive correlation between Ti and Zr, however, is more difficult to account for, since the Ti is mainly present in the form of sphene, which alters more readily than zircon. Since a similar unexpected pattern also appears for Rb, it is assumed that both Rb and Ti were originally incorporated in biotite which survived the weathering only to be later transformed into chlorite + sphene pseudomorphs by metamorphic alteration.

In a ternary Rb-Zr-Ti diagram, the chemical differences between the two groups of "eurites", which show up so well in most of

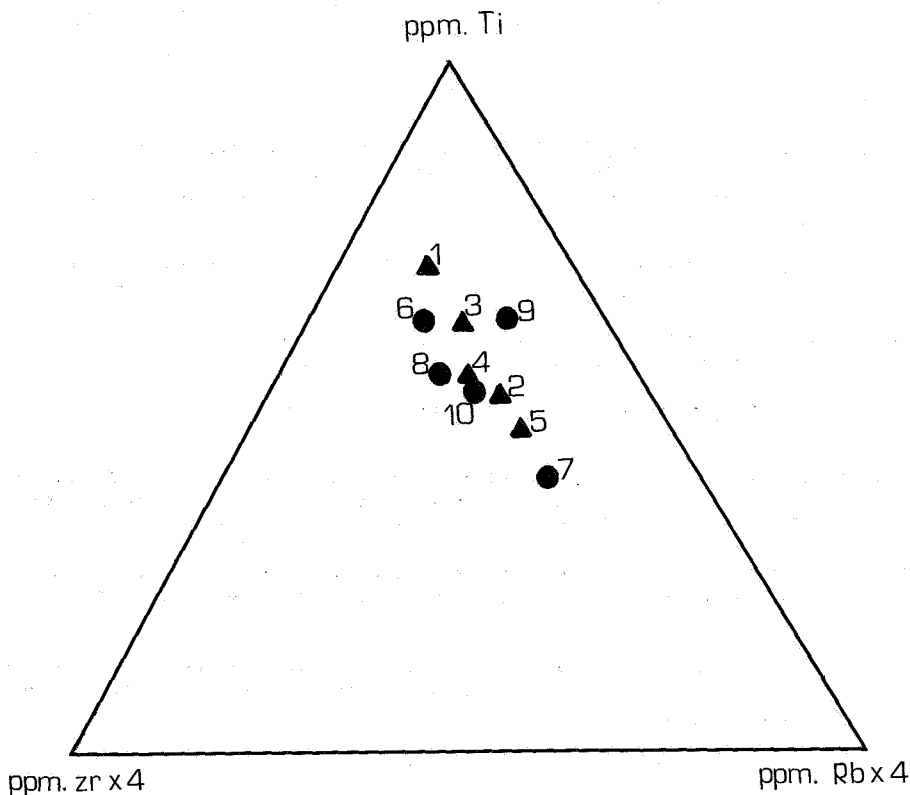


Fig. 3 Rb-Zr-Ti ternary plot; numbers refer to Table 1.

the diagrams, can no longer be distinguished (samples 1 and 7 fall at the extreme ends of the cluster, which may explain their deviant behavior in the Zr-Mn, Zr-Sr and Zr-Rb plots). Since Fig. 2B suggests that these three elements (Zr, Rb, Ti) are not removed from the system during weathering, and since also Jack and Carmichael (1969) have shown that in areas of acid volcanicity each event is marked by its own distinctive trace-element pattern, the conclusion

is drawn that the intrusive and extrusive acid magmatic rocks of the Stavelot complex are cogenetic; that the extrusive rocks (presumably tuffs) suffered weathering while exposed at the surface and that they were later subjected to a low-grade metamorphism which transformed the biotite into chlorite plus sphene.

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Tussenkomst van de Heer VAN BOCKSTAEL :

Is het aangetoond verband tussen de tuffen en de massieven van de Helle niet eerder een gevolg van de verweringsprocessen en van de hydrothermale uitloging zelf dan van een mogelijk genetisch verband tussen deze 2 verschillende magmatische groepen ?

Antwoord van de Heer DANEELS :

Nee, want het verband kan slechts aangetoond worden met die elementen die gezien hun aard niet of nauwelijks direct door verwerking worden beïnvloed. Voor de elementen uit makkelijk verwerende mineralen bestaat een goede correlatie met de weathering potential index en op basis van die elementen ook is het mogelijk chemisch onderscheid te maken tussen opperte afzettingen en dieptegesteenten.



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