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Mineral Deposits at the Beginning of the 21st Century

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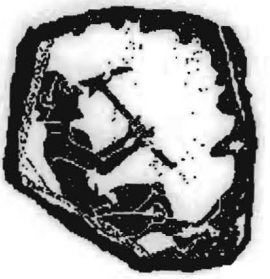

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Mineralogy of pegmatite with giant epidote crystals, near Čanište, Macedonia

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ABSTRACT: Giant epidote crystals up to 2m long have the formula: $(Ca_{1.98}Mn_{0.02})_{\Sigma}Al_{2.45}Fe_{0.53}Ti_{0.01}(SiO_4)(Si_2O_7)O(OH)$, and unit cell parameters: a=8.890(2)Å, b=5.634(2)Å, c=10.147(2)Å, β=115.40(2)°, and V=459.1(2)Å^3. Epidote is in association with albite, microcline (amazonite variety), muscovite, garnet, titanite and zircon. Crystallization temperature is estimated to be about 400°C on the basis of two feldspars thermometer.

1 GEOLOGICAL SETTING OF PEGMATITES

Vein type rocks are present as pegmatites, aplites and quartz veins in the Pelagon metamorphic complex.

Pegmatites are located in the near rim parts of the granodiorite-adamellites, most commonly in gneisses, being totally absent in mica schists. They vary in size and strike extension. Individual bodies are from several to one hundred meters long. The discordant pegmatite veins in Mt Selečka cut across gneiss foliation. The relationship between pegmatites and aplites indicates that they formed simultaneously. In several places gradual transition from pegmatites to aplites can also be noticed.

A number of pegmatite bodies of various size, shape and composition can be found near the villages of Krušejca, Čanište and Manastir. The terrain in which these bodies are situated is part of the Pelagon and is composed of Precambrian igneous (granites) and metamorphic (orthogneisses and gneissic granite) rocks. The rocks are of NNE - SSW extension and are subvertical.

The Čanište pegmatite occurrence is situated in the Dimov Dol site in close proximity to the Prilep - Vitolište asphalt road. Based on field investigations it can be said that the pegmatite occurrence is of NE - SW strike with a subvertical angle of almost 65-85°.

The occurrence is a large lens-like body with thickening in its centre and thinning at both ends. The body is built next to potassium-sodium feldspar, quartz and small quantities of mica, epidote and zircon. Potassium and sodium feldspars seldom have regular crystal shapes but irregular shapes of various sizes. It is white, sometimes pinkish. Occurrences of amazonite can also be seen in some localities in Čanište. Quartz occurs as granular veins or veinlets and blocks of various sizes. It is milky white and sooty-grey. Milky white quartz occurs in the core and behaves as monomineral mass, whereas the greyish quartz occurs along with feldspar. Mica occurs as small nests and epidote occurs with regular crystal shapes of greenish colour. Zonation characterised by quartz and potassium feldspar in the central parts with a zone of sodium feldspar, quartz and epidote around them can also be noticed in the pegmatites in Čanište.

2 EXPERIMENTAL

All samples were analyzed with a JEOL 733 electron microprobe equipped with the Tracor Northern 5500 and 5600 automation. A 20 micron beam diameter was used for all analyses. 100 second EDS scans was used on all samples to look for trace elements. No other elements with Z higher than 8 other than those reported here were detected. The data was collected for 25 seconds for all elements other than. the trace elements in the feldspars Here Pb was collected for

Table 1: Representative analyses of EPIDOTE (epidote - 7255/2) from Čanište pegmatite body. K, Na, and Mg are below detection limit.

	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9
CaO	22.64	22.73	22.78	22.77	22.62	22.36	23.32	22.99	23.17
MnO	0.44	0.41	0.44	0.55	0.49	0.49	0.25	0.36	0.25
Al_2O_3	22.98	22.80	22.84	22.50	22.63	22.57	26.19	24.33	26.10
Fe_2O_3	12.87	13.06	13.06	13.11	13.33	13.07	8.90	11.20	8.78
TiO_2	0.00	0.09	0.00	0.08	0.00	0.00	0.09	0.07	0.12
SiO_2	36.82	36.74	37.36	36.86	36.79	36.88	37.45	37.07	37.66
H_2O*	1.84	1.84	1.85	1.84	1.84	1.83	1.88	1.86	1.88
TOT	97.59	97.67	98.34	97.70	97.70	97.20	98.08	97.87	97.99
Ca^{2+}	1.976	1.985	1.973	1.990	1.976	1.960	1.995	1.989	1.981
Mn^{2+}	0.031	0.028	0.030	0.038	0.034	0.034	0.017	0.025	0.017
Al^{3+}	2.207	2.190	2.176	2.163	2.175	2.176	2.464	2.315	2.455
Fe^{3+}	0.789	0.801	0.794	0.805	0.818	0.805	0.535	0.680	0.527
Ti^{4+}	0.000	0.005	0.000	0.005	0.000	0.000	0.005	0.004	0.007
Si^{4+}	3.000	2.995	3.020	3.006	3.000	3.017	2.990	2.993	3.005
H^+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CATS	8.002	8.004	7.994	8.006	8.003	7.992	8.006	8.006	7.997
O	13	13	13	13	13	13	13	13	13

* Determined by stoichiometry

Table 2: Representative microprobe analyses of feldspar minerals from Čanište pegmatite. Sr, Mn, and P are below the detection limits. PT1 to PT3 albite (7255/2) PT4 to PT6 – albite zone in amazonite microcline, PT7 to PT9 – amazonite microcline.

	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8	PT9
Na_2O	11.36	11.28	11.17	11.39	11.52	11.65	0.66	0.84	0.42
K_2O	0.07	0.08	0.12	0.12	0.07	0.13	15.62	15.25	15.79
Rb_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.25	0.11
Cs_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06	0.00
CaO	0.31	0.29	0.72	0.21	0.15	0.14	0.00	0.00	0.00
BaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
PbO	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.41	0.14
Al_2O_3	20.08	19.93	20.52	19.63	19.81	19.68	18.25	18.38	18.61
Fe_2O_3	0.00	0.00	0.06	0.06	0.06	0.06	0.00	0.00	0.00
SiO_2	68.91	68.87	68.12	69.31	69.52	69.23	65.24	64.54	64.47
TOT	100.73	100.45	100.71	100.73	101.13	100.90	100.40	99.73	100.12
Na^+	0.954	0.949	0.940	0.956	0.963	0.978	0.059	0.075	0.038
K^+	0.004	0.005	0.007	0.007	0.004	0.007	0.919	0.903	0.934
Rb^+	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.003
Cs^+	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
Ca^{2+}	0.015	0.013	0.034	0.010	0.007	0.006	0.000	0.000	0.000
Ba^{2+}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Pb^{2+}	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.005	0.002
Al^{3+}	1.025	1.020	1.050	1.002	1.007	1.004	0.992	1.006	1.016
Fe^{3+}	0.000	0.000	0.002	0.002	0.002	0.002	0.000	0.000	0.000
Si^{4+}	2.985	2.990	2.958	3.001	2.998	2.996	3.008	2.996	2.988
CATS	4.982	4.977	4.990	4.978	4.981	4.993	4.989	4.994	4.991
O	8	8	8	8	8	8	8	8	8

Formula contents on the basis of 8 anions

Table 3: Separate geothermometers Kfs+Pl

Pressure (kbar)	2	4	6	8	10	12
STORMER J.C.,JR. (1975)	370	388	406	425	443	461
WHITNEY J.A., STORMER J.C.,JR. (1977)	417	436	455	473	492	511
POWELL M., POWELL R. (1977)	370	389	407	425	444	462
FERRY J.M. (1978)		431				
HASELTON H.T. ET AL. (1983)	320	340	361	382	402	423
Average	369	397	407	426	445	464

100 seconds.

The X-ray diffraction data sets were collected up to 30°Θ on a Philips 1100 powder diffractometer using Cu K_α radiation filtered with graphite monocrystal monochromator. Indexed powder diffraction patterns were used for calculation of unit cell parameters for all separated minerals.

3 RESULTS

Giant epidote crystals up to 2 m long are probably the biggest known crystals of epidote. They have moreover, evidently crystallized during formation of the pegmatite body. Within the same crystal two distinct colour zones are observed due to different colours. The epidote appears with a high clinozoisite and minor piemontite in composition.

Composition and formula units calculated on the basis of 13O is shown in Table 1. Grayish green epidote has unit cell parameters: a=8.890(2) Å, b=5.634(2) Å, c=10.147(2) Å, β=115.40(2)°, and V=459.1(2) $Å^3$.

Two feldspars were identified from the pegmatite body associated with the giant epidote crystals: 1) Large, white crystals of albite with unit cell dimensions: a=8.145(3) Å, b=12.784(5) Å, c=7.158(3) Å, α=94.26(4)°, β=116.58(3)°, γ=87.77(4)°, and V=665.3(3) $Å^3$. The albite is usually a little bit sericitized. 2) Amazonite microcline with unit cell parameters: a=8.584(4) Å, b=12.980(6) Å, c=7.219(3) Å, α=90.79(6)°, β=115.96(3)°, γ=87.60(4)°, and V=721.5(4) $Å^3$. There are white zones of albite within amazonite microcline, which are assumed to have crystallized together. Chemical composition is showed in Table 2.

Exsolution of albite within microcline crystals allowed us to estimate the temperature of crystallization of minerals in these pegmatite bodies. Depending on assumed pressure and applied thermometer this temperature can be estimated to be between 370 and 465°C, assuming that pressure was not less than 3 Kbar (Table 3.).

Microscopic examinations distinguished a few types of fluid inclusions in bothside polished, 0.1-0.2 mm thick epidote wafers.

Table 4: Representative analyses of GARNET from pegmatite body containing giant epidote crystals, Čanište, Macedonia.

	1	2	3
CaO	15.98	15.94	15.75
MgO	0.27	0.29	0.30
MnO	6.91	6.57	6.70
FeO	16.87	16.67	16.66
Al_2O_3	20.07	20.18	19.97
TiO_2	0.35	0.36	0.32
SiO_2	37.00	37.38	37.14
Fe_2O_3*	1.65	1.56	1.71
TOTAL	99.10	98.95	98.55
Ca^{2+}	1.376	1.368	1.360
Mg^{2+}	0.032	0.035	0.036
Mn^{2+}	0.470	0.446	0.457
Fe^{2+}	1.134	1.117	1.123
Al^{3+}	1.901	1.906	1.896
Ti^{4+}	0.021	0.022	0.019
Si^{4+}	2.973	2.995	2.993
Fe^{3+}	0.099	0.094	0.104
CATSUM	8.006	7.983	7.988
O	12	12	12

Microthermometric measurements, performed on fluid inclusions of type NaCl-H_2O-CO_2, suggest the presence of other volatile components, probably CH_4 or N_2. Salinity is moderate to low. Homogenization of the carbonic phase proceeds in two ways, L+V→L, L+V→V, and critical phenomena has not been observed. The data gather around 28°C in either ways of homogenizations.

Garnet crystals are not very common. They are up to 2 cm in size and have deep red colour. Garnet was previously erroneously identified optically as andradite in composition (4129). On the basis of electron microprobe analyses the garnet is predominantly grossular with a large almandine component (Table 4.). Its unit cell parameter is a=11.713(2)Å and V=1607(1)$Å^3$. (Grossular has a=11.851Å and almandine a=11.526Å).

The other important components are spessartine and minute pyrope (Table 4).

Pink crystals of zircon are up to a few cm long. It was very pure with only Zr, Hf and Si detected (Table 5). Its unit cell parameters are a=6.811(4) Å, c=5.988(6) Å, and V=261.7(3) $Å^3$.

Table 5: Representative microprobe analyses of ZIRCON. PT 1-3 represent 3 analyses on the sample (zircon - 3788/2). Y, La, Ce, Pr, Nd, Sm, Gd, Er, Yb, Ti, Th, and U are below the detection limits.

	PT1	PT2	PT3
ZrO_2	64.73	64.83	64.93
HfO_2	2.71	2.79	2.81
SiO_2	32.36	32.50	32.46
TOTAL	99.80	100.12	100.2
Zr^{4+}	0.976	0.974	0.975
Hf^{4+}	0.024	0.025	0.025
Si^{4+}	1.000	1.001	1.000
CATSUM	2.000	2.000	2.000
O	4	4	4

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Metamorphism affecting mineral deposits

Industrial mineral deposits