

EDITORIAL: AN ELECTRONIC VERSION OF
THE CANADIAN MINERALOGIST

I am happy to announce that beginning with the next issue, Volume **38**, we will be producing both an electronic version and a paper version of *The Canadian Mineralogist*. In so doing, the Mineralogical Association of Canada has taken a proactive stand in view of irreversible changes that are taking place in the field of scholarly publications. For us, this is another adventure into unknown territory. Fortunately, in view of limited financial resources and staff, others have been there, made the inevitable mistakes, and are now in a position to help us make the transition in a smooth and seamless way, with a minimum of delay.

The decision to produce an electronic version came in response to inquiries concerning the availability of our journal on the WEB, and the cost of site licenses. These inquiries came from organizations that are interested in having *The Canadian Mineralogist* available at the terminal of every staff member. We are, of course, drawn into this area of activity by the availability on the WEB of scholarly journals produced by profit-driven publishers. We thus anticipate that by going on the WEB, the sphere of influence of our journal will broaden considerably.

To a university library, *The Canadian Mineralogist* costs a small fraction of the cost of most journals in the Earth Sciences. In my opinion, the quality of the journal we publish is first-rate, and the journal is very highly regarded internationally. In spite of this admittedly biased assessment, libraries in some academic institutions, for example the one at McGill University, where I work, are faced with such a serious financial crunch that just about every scholarly journal is getting cut, at least those in the area of the Earth Sciences. In the current context, money is available for site licences to electronically produced journals and for books, and that's about all. Thus next year, the paper version of *The Canadian Mineralogist* will be cut, such that our decision to publish an electronic version is very timely. The librarians have adopted the tacit stand that if a journal is any good, then by definition it is available on the WEB. We have been placed in a sink-or-swim situation, and we intend to swim!

The Mineralogical Association of Canada will continue to produce a paper version of *The Canadian Mineralogist*. We have signed a contractual agreement with NRC Research Press to produce the electronic version; articles will be available in PDF format. NRC Research Press is part of the Canada Institute for Scientific and Technical Information (CISTI). It publishes fourteen journals, all of them in paper and electronic versions. The one you are likely to know best is the *Canadian Journal of Earth Sciences*. NRC Research Press will work with us to produce a quality product according to the protocols that they have developed for their own journals. Part of their mandate is to remain at the forefront of Canadian scientific publishing. Thus a significant investment has been made to develop electronic publishing capabilities. Another part of their mandate is to share this practical knowledge with small non-profit societies like ours, to allow them to participate in the explosion of WEB-based resources. Interestingly for the MAC, NRC Research Press already has well-established contacts with subscription agents and other suppliers of electronic information. For all practical purposes, the contents of *The Canadian Mineralogist* will be offered to these middle men as if our journal had become the fifteenth NRC

journal.

For the first year of operation at least, WEB access to *The Canadian Mineralogist* will be free to personal subscribers. The MAC will work closely with NRC Research Press concerning the sales of corporate electronic subscriptions and site licenses according to an equitable fee structure. More details will be forthcoming in the MAC Newsletter and in forthcoming issues of this journal. I applaud the decisions of the Executive Council of the Mineralogical Association of Canada to promote *The Canadian Mineralogist*, first to expand the journal from four to six issues per year, then to cover entirely the extra costs of publishing in color, and now to reach out to new (and existing) audiences *via* our WEB site, www.mineralogicalassociation.ca/.

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NOMENCLATURE OF THE ALUNITE SUPERGROUP

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ABSTRACT

The alunite supergroup consists of more than 40 mineral species with the general formula $DG_3(TO_4)_2(OH, H_2O)_6$, in which D is occupied by monovalent (*e.g.*, K, Na, NH_4 , H_3O), divalent (*e.g.*, Ca, Ba, Pb), or trivalent (*e.g.*, Bi, *REE*) ions, G is typically Al^{3+} or Fe^{3+} , and T is S^{6+} , As^{5+} , or P^{5+} . The current nomenclature classification is unusual in that, within the ternary system defined by the SO_4 , AsO_4 , and PO_4 apices, compositions are divided into five fields rather than the three that are conventionally recommended for such systems by the Commission on New Minerals and Mineral Names (CNMMN) of the International Mineralogical Association. The current compositional boundaries are arbitrary, and the supergroup is examined to determine the repercussions that would ensue from adoption of a conventional ternary compositional system. As a result of the review, several inconsistencies have been revealed; for example, beaverite and osarizawaite, which are commonly formulated as $Pb(Cu,Fe)_3(SO_4)_2(OH)_6$ and $Pb(Cu,Al)_3(SO_4)_2(OH)_6$, respectively, not only have formula $Fe > Cu$ and $Al > Cu$, but the amount of substitutional Cu also is variable. Beaverite is therefore compositionally equivalent to Cu-bearing plumbojarosite. The CNMMN system also permits the introduction of new mineral names if a supercell is present; within the alunite supergroup, the supercell is typically manifested by a doubling of the c axis to ~ 34 Å, and the effect is evident on X-ray powder patterns by the appearance of a diffraction line or peak at 11 Å. In addition to the supercell, however, several other departures from the standard trigonal cell with space group $R\bar{3}m$ have been observed. To accommodate these structural variations, thereby minimizing the introduction of numerous potential new mineral names, the possibility of incorporating a suffix modifier is explored. To keep within CNMMN nomenclature protocols, potential solutions are offered, but none is proposed.

Keywords: alunite supergroup, nomenclature, alunite group, beudantite group, crandallite group, compositions, structures.

LUDWIGITE FROM THE TYPE LOCALITY, OCNA DE FIER, ROMANIA: NEW DATA AND REVIEW

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ABSTRACT

Ludwigite from the type locality, Ocna de Fier, Banat, Romania, was re-investigated in order to establish undocumented chemical and physical properties. The mineral occurs in boron-bearing magnesian skarns, in a restricted association that includes calcite, forsterite (fayalite 0.92–2.60%, tephroite 0.75–1.26%), magnetite (magnesioferrite 18.48–46.31%) and clinohumite ($X_{\text{Fe}} = 0.59\%$, $X_{\text{F}} = 40.91\%$). The host skarns are developed at the contact between an intrusive Upper Cretaceous ("banatitic") body, which is mainly granodioritic, and metasomatized Mesozoic limestones. Ludwigite from Ocna de Fier is closer to the magnesian end-member than previously reported. The analyzed samples are compositionally variable, with vonsenite ranging from 4.41 to 14.27 mol.%, minor azoproite [up to 0.10 mol.% $(\text{Mg}, \text{Fe}^{2+})_2(\text{Ti}^{4+}, \text{Mg})(\text{BO}_3)_2\text{O}_2$], and less than 6.55 mol.% $(\text{Mg}, \text{Fe}^{2+})_2\text{Al}(\text{BO}_3)_2\text{O}_2$ in solid solution, and with minor Sn, Sb, Cr, Ni, Co, Mn and Zn. Cell parameters [a 9.225(8) – 9.290(6), b 12.233(9) – 12.334(6), c 3.033(4) – 3.057(3) Å] are influenced by both Fe^{2+} and Al contents. The mean reflectance is approximately 11%, and the mean index of refraction is 1.95. A strong magnetic anisotropy is observed; the maximum of susceptibility ($12511.76 \cdot 10^6$ e.m.u.) was measured along a direction coincident with fiber elongation. The Mössbauer spectrometry indicates the superparamagnetic behavior of the mineral. The splitting of internal vibrational modes of BO_3 group in the infrared spectra is consistent with a C_{3v} or C_s point symmetry of the BO_3 group, which is characteristic for magnesian ludwigite. Heated in air, the mineral is stable up to 1000°C. The compositional data, combined with information on the experimental synthesis of borates, indicate a temperature of crystallization at 600–650°C and oxygen fugacities of 10^{-18} – 10^{-14} atm.

Keywords: ludwigite, magnesian skarns, X-ray data, thermal behavior, magnetic behavior, Mössbauer spectroscopy, infrared-absorption data, crystal chemistry, Ocna de Fier, Romania.

THE DIFFERENTIAL THERMAL ANALYSIS OF GAUDEFROYITE

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ABSTRACT

Gaudefroyite, $\text{Ca}_8\text{Mn}^{3+}_6[(\text{BO}_3)_6(\text{CO}_3)_2\text{O}_6]$, from the Wessels mine in the Kalahari manganese field, South Africa, was studied using a Netzsch STA 409 EP/3/D simultaneous TG–DTA equipment. A finely powdered sample of gaudefroyite was heated from 20 to 1450°C at a rate of 5°C/min. The thermogravimetric (TG) and differential thermal analysis (DTA) results indicate that gaudefroyite possibly contains one polymorphic transition at a peak temperature of 1004°C. This transition is interpreted as the change from partial ordering to complete disordering of CO_3 groups. The loss of $\text{CO}_2(\text{g})$ occurs at a peak temperature of 1053°C. Similar changes take place in cancrinite; the disordering of CO_3 groups occurs at 868°C, and the loss of $\text{CO}_2(\text{g})$ occurs at a peak temperature of 949°C. The corresponding changes occur at higher temperatures in gaudefroyite than in cancrinite because the $(\text{CO}_3)^{2-}$ groups are surrounded by six Ca^{2+} cations, which results in strong bonds, whereas in cancrinite, they are surrounded by four Na^+ and two Ca^{2+} cations, resulting in weaker bonds. The TG–DTA results strongly indicate that the CO_3 groups in gaudefroyite are partially ordered and possibly give rise to a superstructure.

Keywords: gaudefroyite, order, CO_3 groups, superstructure, differential thermal analysis, thermogravimetric analysis.

THE MINERALOGY OF A UNIQUE BARATOVITE- AND MISERITE-BEARING QUARTZ
– ALBITE – AEGIRINE ROCK FROM THE DARA-I-PIOZ COMPLEX, NORTHERN
TAJKISTAN

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ABSTRACT

Metasomatic rocks of the Dara-i-Pioz alkaline complex in northern Tajikistan are known to contain a great variety of rare silicates enriched in Li, B, F and incompatible elements. One example is a quartz – albite – aegirine rock from the Upper Dara-i-Pioz intrusion, which is interpreted as a product of metasomatic alteration of an alkaline syenite parent. The bulk of the rock, an assemblage of aegirine–hedenbergite, albite, microcline and fluorapatite, formed during an albitization event. Unusual K–Ca silicates that crystallized during this stage include baratovite $\text{KLi}_3\text{Ca}_7\text{Ti}_2[\text{Si}_6\text{O}_{18}]_2\text{F}_2$, miserite $\text{K}_{1.3}(\text{Ca},\text{REE})_6[\text{Si}_8(\text{O},\text{OH})_{22}](\text{OH},\text{F})_2$ and turkestanite $(\text{K},\text{Pb})_{0.5}(\text{Ca},\text{Na},\text{REE},\text{Pb})_2(\text{Th},\text{U},\text{REE})[(\text{Si},\text{Al})_8\text{O}_{20}]$ (formulae given on the basis of compositional data). Sr-bearing calcite postdates the albitization assemblage, and may be a manifestation of a distinct metasomatic event (carbonatization). Conspicuous strain-induced features exhibited by the clinopyroxene, quartz, baratovite, miserite, microcline and calcite indicate that the rock underwent deformation during the late stages of crystallization. Deformation-induced fracturing of the rock facilitated circulation of a relatively low-temperature fluid enriched in B, F, Ti and incompatible elements. The fluid precipitated datolite, fluorite, quartz, and a rich diversity of rare minerals containing REE, Ba, Zr, Sn, Hf and Nb. The REE are concentrated predominantly in the borosilicates tadhikite $\text{Ca}_{3.2-3.8}\text{LREE}_{1.0-1.8}\text{Y}_{0.1-0.9}(\text{Ti},\text{Fe},\text{Al})_{1.0}[\text{B}_4\text{Si}_4\text{O}_{20.3}(\text{OH})_{1.7}](\text{OH})_2$ and stillwellite-(Ce) $\text{LREE}[\text{BSiO}_5]$. The new analytical data confirm the existence of two distinct mineral species, “tadhikite-(Y)” and “tadhikite-(Ce)”. The high-field-strength elements and Ti are concentrated in titanite (≤ 8.1 wt.% SnO_2 , 2.3 wt.% ZrO_2 and 1.7 wt.% Nb_2O_5), bazirite (≤ 2.9 wt.% SnO_2 , 2.1 wt.% HfO_2) and zircon (≤ 3.2 wt.% HfO_2). The B–F-enriched fluid may have

been derived from alkaline pegmatites that cut the metasomatic suite and contain a similar assemblage of rare minerals.

Keywords: aegirine, baratovite, bazirite, miserite, stillwellite, tadzhikite, titanite, metasomatic assemblage, alkaline complex, Dara-i-Pioz, Tajikistan.

CHLORINE-BEARING AMPHIBOLES FROM THE FRASER MINE, SUDBURY, ONTARIO, CANADA: DESCRIPTION AND CRYSTAL CHEMISTRY

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ABSTRACT

Three chemically distinct populations of Cl-bearing amphibole have been recognized in association with contact Ni–Cu ore deposits in Footwall Breccia at the Fraser mine, Sudbury, Ontario. The first population, defined as halogen-poor (<0.5 wt.% Cl) actinolite and magnesiohornblende, occurs predominantly as pale green grains and cores. These are generally overgrown by amphibole of the other two populations: a) Fe-rich, halogen-poor deep green rim of ferro-actinolite to ferrohornblende, or b) Fe-rich, Cl-rich (up to 4 wt.% Cl) ferrotschermakite to hastingsite to potassic-chlorohastingsite, which exhibits a characteristic deep blue-green pleochroism. Rare F-rich (up to 1.1 wt.% F) magnesiohornblende also is observed in the same environment. Major-element data for the Cl-rich amphiboles indicate linear, positive relationships for both Mg# and K *versus* Cl, and a logarithmic, positive one for ⁴⁴Al *versus* Cl. These data, along with selected X-ray maps, indicate that Cl is homogeneously distributed and likely structurally bound. Calculated Fe³⁺/Fe²⁺ values suggest crystallization under conditions of relatively low *f*(O₂). At least two chemically distinct fluids seem to have been responsible for crystallization of the amphiboles. The first, which resulted in the crystallization of halogen-poor, pale green actinolite and magnesiohornblende, was likely relatively hot (≥650°C) and contemporaneous with sulfide emplacement. This was followed by a lower-*T* (≥350°C), Cl-rich fluid from which the Cl-rich amphiboles crystallized. This latter fluid may have been a modified product of the initial fluid or possibly a second discrete fluid. A subsequent F-rich fluid led to development of F-rich magnesiohornblende. The source of both Cl and F is not clear; whole-rock analyses of Footwall rocks of the Levack Gneiss Complex however, reveal anomalous enrichments in both Cl (>700 ppm) and F (2500 ppm). These rocks thus may have been a significant contributor to the fluids.

Keywords: amphibole, chemical composition, chlorine, halogens, fluids, contact sulfide deposits, Ni–Cu ore, Footwall Breccia, Sudbury, Ontario, Canada.

PARAGENESIS AND MINERAL CHEMISTRY OF AMPHIBOLE AND BIOTITE IN THE
MacLELLAN GOLD DEPOSIT, LYNN LAKE GREENSTONE BELT, MANITOBA,
CANADA

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ABSTRACT

The Proterozoic MacLellan gold deposit, in the Lynn Lake greenstone belt, Manitoba, developed through a complex sequence of pre-, syn- and postmetamorphic fluid-infiltration events within a series of amphibolite-grade biotite-, chlorite- and amphibole-bearing schists. Amphibole within the deposit is manifested as a wide variety of textural types, including metamorphic porphyroblasts, randomly oriented, postmetamorphic porphyroblasts and aggregates, amphiboles related to quartz – chlorite – biotite vugs, and aggregates of massive amphibole in alteration haloes around veins. The amphiboles are all calcic, but represent a wide compositional range, and includes the varieties ferrotschermakite, tschermakite, magnesiohornblende and actinolite. Distribution of Fe and Mg among amphibole, biotite and chlorite indicate three amphibole-forming events, which represent 1) metamorphism, 2) the main quartz–amphibole vein-forming and alteration event, and 3) an event that formed the vugs. The randomly oriented porphyroblasts and aggregates appear to be associated with both the main alteration event and the vug-forming event, which is consistent with their formation after the main episode of metamorphism and deformation. The chemical composition of the protolith strongly influenced the chemistry of alteration amphiboles. Alteration occurred under low water:rock ratios. Biotite, the other main mafic mineral, is generally Mg-rich. The composition of biotite in and around metamorphosed quartz – biotite – sulfide (QBS) veins is more restricted than that of the host-rock biotite, which suggests that these compositions represent a fluid-buffered protolith composition. Titanium contents of the biotite correlate with the nature of the associated Ti-oxide phase, increasing from rutile to ilmenite ± rutile to titanite – ilmenite ± rutile. The QBS-associated biotite typically has a high Ti content and is associated with titanite. This association may well result from premetamorphic metasomatism related to the QBS vein-forming event.

Keywords: amphibole, biotite, mineral composition, gold, MacLellan deposit, paragenesis, hydrothermal, Lynn Lake greenstone belt, Manitoba.

THE OXIDATION RATIO OF IRON IN COEXISTING BIOTITE AND HORNBLENDE
FROM GRANITIC AND METAMORPHIC ROCKS: THE ROLE OF P, T AND $f(\text{O}_2)$

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ABSTRACT

Previously published and new data on the composition of coexisting biotite and hornblende from granitic and metamorphic rocks show that the degree of iron oxidation, $R [= \text{Fe}^{3+}/(\text{Fe}^{2+} + \text{Fe}^{3+})]$, is different in these two minerals; the R of hornblende is greater. Granulite-facies minerals have the greatest difference in R , whereas in granitic rocks, those minerals show the least difference. The oxidation of biotite and hornblende under high-level conditions is accompanied by the crystallization of magnetite, and newly formed oxidized mafic minerals have a lower $\text{Fe}/(\text{Fe} + \text{Mg})$ and R than the original ones. Under mesozonal and catazonal conditions, the increase in pressure prevents the formation of magnetite, and oxidation is accompanied by a significant increase in R ; these changes in the chemical composition of hornblende are supplemented by an increase in Al. Since the Al content of hornblende is known to be an indicator of pressure, such a correlation of R and Fe^{3+} content with aluminum content points to an increase of these parameters with a rise of pressure.

Keywords: biotite, hornblende, oxidation ratio, granitic rocks, metamorphic rocks, epizonal plutons, mesozonal plutons, catazonal plutons.

THE OCCURRENCE AND CRYSTAL STRUCTURE OF FOITITE FROM A TUNGSTEN-BEARING VEIN AT COPPER MOUNTAIN, TAOS COUNTY, NEW MEXICO

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ABSTRACT

Foitite, an X-site-vacant tourmaline, occurs in both cross-fiber and slip-fiber textures with scheelite and wolframite in a quartz vein cutting metaquartzite of the Proterozoic Ortega Formation at the Tungsten (or Wichita) mine on Copper Mountain, Picuris Range, Taos County, New Mexico. The tourmaline is brown, and its indices of refraction $\epsilon = 1.634(2)$ and $\omega = 1.666(2)$. It is strongly pleochroic, with *E* brown and *O* colorless. The density is 3.17(2) (meas.) and 3.20 g/cm³ (calc.). Unit-cell parameters refined from powder X-ray data are *a* 15.973(1), *c* 7.137(1) Å, and *V* 1576.8(2) Å³. The atomic arrangement of the Copper Mountain foitite was refined to *R* = 0.018 using three-dimensional X-ray data. The structural study confirms the low occupancy of the *X* site, and demonstrates that the atomic arrangement is essentially identical to that of the type material from southern California. Mössbauer spectroscopy shows that the iron is entirely ferrous, which indicates that the foitite crystallized at an oxygen fugacity below that of the quartz – fayalite – iron buffer and,

perhaps, as low as that of the iron – wüstite buffer.

Keywords: foitite, tourmaline, chemical composition, crystal structure, Copper Mountain, New Mexico.

MAGNESIOFOITITE, **G** (Mg₂Al) Al₆ (Si₆O₁₈) (BO₃)₃ (OH)₄, A NEW ALKALI-DEFICIENT TOURMALINE

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ABSTRACT

Magnesiofoitite is a new tourmaline species from an alteration zone in a silicified porphyry developed in completely altered andesitic to dacitic volcanic rocks at Kyonosawa, Mitomi-mura, Higashi-Yamanashi-gun, Yamanashi-ken Prefecture, Honshu, Japan. It occurs as bluish grey individual crystals and felted masses on fracture and void surfaces; individual crystals average ~5 mmm wide and 50 mmm long, and a few crystals approach 15 mmm wide and 1 mm long. It is brittle, $H = 7$, $D_{\text{calc}} = 2.995 \text{ g/cm}^3$. In plane-polarized light, magnesiofoitite is pleochroic, O = grey-blue, E = pale lavender, with moderate absorption, $\omega > \epsilon$; it is uniaxial negative, $\omega = 1.624$, $\epsilon = 1.650$, trigonal,

space group $R3m$, in the hexagonal setting, with a 15.884(4), c 7.178(3) Å, V = 1568.0(6) Å³, Z = 3. The strongest six X-ray-diffraction lines [d in Å(I)(hkl)] are: 3.969(100)(220), 2.567(100)(051), 4.211(90)(211), 2.949(70)(122), 6.366(60)(101), and 3.470(60)(012). A chemical analysis gave (in wt.%), SiO₂ 38.27, Al₂O₃ 40.17, FeO 0.97, MgO 6.15, Na₂O 0.70, B₂O₃(calc.) 11.09, H₂O(calc.) 3.82, sum = 101.17 wt.%; P, Ti, Ca, Mn, Zn, K and F were not detected. The formula unit, calculated for 6 Si *apfu* (atoms per formula unit) with B = 3.0 *apfu* and OH = 4.0 *apfu*, is ^X(G_{0.79}Na_{0.21})^Y(Mg_{1.44}Fe_{0.13}Al_{1.42})^ZAl₆(Si₆O₁₈)(BO₃)₃(OH)₄, with the ideal end-member formula **G**(Mg₂Al)Al₆(Si₆O₁₈)(BO₃)₃(OH)₄, where **G** represents a vacancy. Thus magnesiofoitite is an X-site-vacant tourmaline; it is derived from foitite, **G**(Fe²⁺₂Al)Al₆(Si₆O₁₈)(BO₃)₃(OH)₄ by the homovalent substitution ^YMg → ^YFe²⁺, and from dravite, NaMg₃Al₆(Si₆O₁₈)(BO₃)₃(OH)₄ by the heterovalent substitution ^X**G** + ^YAl → ^XNa + ^YMg. The new species and name were approved by the CNMMN of the IMA.

Keywords: magnesiofoitite, tourmaline, new mineral species, Kyonosawa, Honshu, Japan.

FERROKINOSHITALITE, A NEW SPECIES OF BRITTLE MICA FROM THE BROKEN HILL MINE, SOUTH AFRICA: STRUCTURAL AND MINERALOGICAL CHARACTERIZATION

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ABSTRACT

Ferrokinoshitalite, ideally $\text{BaFe}^{2+}_3(\text{Si}_2\text{Al}_2)\text{O}_{10}(\text{OH})_2$, is the iron-rich analogue of kinoshitalite, and thus a new species of the brittle mica group. Samples commonly have considerable chemical substitutions with large cations (*e.g.*, K, Na) for Ba, medium-size cations (*e.g.*, Mg, Mn, Ti, Al, Fe^{3+}) in octahedral sites, and F for OH. The color is dark green, the luster is vitreous, thin grains are translucent, the streak is green, the Mohs hardness is 3, the density is 3.69(8) g/cm³ (measured) and 3.59 g/cm³ (calculated), and it has perfect (001) cleavage. From single-crystal determinations, ferrokinoshitalite is monoclinic, space group *C2/m*, with unit-cell parameters *a* 5.389(1), *b* 9.337(2), *c* 10.054(2) Å, β 100.53(2)°. The polytype is 1*M*, and *Z* is equal to 2. The strongest five powder X-ray diffraction lines [*d* in Å(*I*)] are: 2.651(100), 2.176(40), 1.551(30), 1.659(25), and 1.529(25). The mean index of refraction, as determined from the Gladstone–Dale relationship, is 1.6939. The mineral is biaxial negative, and strongly pleochroic. Thermal gravimetric analysis shows a net gain in weight of ~2.4 wt% from 400 to 1000°C, after a small loss in weight of ~0.2% from 24 to 400°C. The weight gain is attributed to iron oxidation, which produces hematite. The crystal structure of ferrokinoshitalite was refined to an agreement factor *R* = 0.032 and *wR* = 0.036 using 750 unique observed reflections on a sample with a structural formula of $(\text{Ba}_{0.47}\text{K}_{0.33}\text{Na}_{0.04}) (\text{Fe}^{2+}_{1.72}\text{Mg}_{0.74}\text{Mn}_{0.08}\text{Fe}^{3+}_{0.15}\text{Ti}_{0.17}) (\text{Si}_{2.44}\text{Al}_{1.56})\text{O}_{10}(\text{OH}_{1.35}\text{F}_{0.65})$. The two independent octahedral sites are marginally different in size (*M1*: 2.120 *versus* *M2*: 2.106 Å). The effect of Fe content on the structures of Ba-rich micas is discussed. The tetrahedral rotation angle, *aaa*, is small at 3.95°, owing to the relatively large size of Fe^{2+} and Ba. Ferrokinoshitalite occurs in massive Pb–Zn–Cu–Ag sulfide orebodies at the Broken Hill mine, northern Cape Province, South Africa, in a mineral assemblage containing quartz + magnetite + spessartine-rich garnet + apatite ± sillimanite ± ferroan gahnite ± sulfides, with Mn-rich grunerite (in

places, manganogrunerite), manganoan fayalite and Mn-rich pyroxferroite also present in amphibole-rich layers. On the basis of previous studies, ferrokinoshitalite is believed to have formed at or near the peak of metamorphism (at $670 \pm 20^\circ\text{C}$ and 4.5 ± 1.0 kbar).

Keywords: banded-iron formation, brittle mica, ferrokinoshitalite, new mineral species, structure determination, sulfide deposits, Broken Hill mine, Cape Province, South Africa.

COSKRENITE-(Ce), $(\text{Ce,Nd,La})_2(\text{SO}_4)_2(\text{C}_2\text{O}_4)\cdot 8\text{H}_2\text{O}$, A NEW RARE-EARTH OXALATE MINERAL FROM ALUM CAVE BLUFF, TENNESSEE: CHARACTERIZATION AND CRYSTAL STRUCTURE*

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ABSTRACT

The new mineral species coskrenite-(Ce) $[(\text{Ce,Nd,La})_2(\text{SO}_4)_2(\text{C}_2\text{O}_4)\cdot 8\text{H}_2\text{O}]$ occurs as transparent, pink- to cream-colored clusters of tabular crystals 0.1 to 1.0 mm across embedded within, or in cavities in, epsomite and “hair salts” (principally apjohnite) at Alum Cave Bluff, Great Smoky Mountains, Tennessee. A complex suite of sulfates occurs in the soil or on the ceiling of a rock shelter, as a result of weathering of pyritic phyllite and evaporation of the resulting solutions. Coskrenite-(Ce) is closely associated with two other new minerals, levinsonite-(Y) $[(\text{Y,Nd,Ce})\text{Al}(\text{SO}_4)_2(\text{C}_2\text{O}_4)\cdot 12\text{H}_2\text{O}]$ and zugshunite-(Ce) $[(\text{Ce,Nd,La})\text{Al}(\text{SO}_4)_2(\text{C}_2\text{O}_4)\cdot 12\text{H}_2\text{O}]$. They are the first natural examples of rare-earth oxalate salts. Coskrenite-(Ce) is triclinic, space group $P\bar{1}$, a 6.007(1), b 8.368(2), c 9.189(2) Å, α 99.90(2), β 105.55 (2), γ 107.71(2)°, V 407.4(2) Å³, and $Z = 1$. The basic structural unit is a four-membered ring of two $REE(\text{O},\text{H}_2\text{O})_9$ polyhedra and two SO_4 tetrahedra, each sulfate tetrahedron sharing two of its vertices with two REE polyhedra. These rings are linked into chains, and adjacent chains are linked by oxalate groups and hydrogen bonds into sheets oriented parallel to $\{001\}$. Adjacent sheets are weakly bonded together through hydrogen bonds. The REE site is nine-coordinated by a distorted monocapped square antiprism of five O and four H_2O , with an average $REE\text{--O}$ distance of 2.518 Å. The strongest lines in the powder-diffraction pattern [d in Å(I)(hkl)] are: 5.48(100)($1\bar{1}0$), 8.52(70)(001), 6.72(60)($01\bar{1}$), 3.84(60)(020,110), 4.26(50)(002,01 $\bar{2}$), 3.35(40)(02 $\bar{2}$), and 2.744(40)($12\bar{2}$, $2\bar{1}\bar{2}$, $1\bar{3}0$, $2\bar{2}0$). Coskrenite-(Ce) is biaxial negative, $\alpha = 1.544(4)$, $\beta = 1.578(4)$, $\gamma = 1.602(4)$, $2V(\text{obs.}) = 65(10)^\circ$, $2V(\text{calc.}) = 69(3)^\circ$ dispersion

medium ($r > v$), and $Z' \wedge c = 21^\circ$ (in plane of cleavage). The mineral is named after its discoverer, T. Dennis Coskren.

Keywords: coskrenite-(Ce), new mineral species, rare-earth oxalate, X-ray data, crystal-structure determination, Alum Cave Bluff, Tennessee.

THE CRYSTAL STRUCTURE OF SCHUILINGITE-(Nd)

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ABSTRACT

Schuilingite-(Nd) from the Kasompi copper mine, Katanga, southern Shaba, Democratic Republic of Congo, crystallizes in the space group $P2_1cn$, with a 7.419(2), b 18.859(3), c 6.395(1) Å, V 894.7(3) Å³, $Z = 4$. The structure of schuilingite-(Nd), $Pb^{2+} Cu^{2+} (REE) (CO_3)_3 (OH) (H_2O)$, has one site occupied by rare-earth elements, REE (predominantly Nd) and coordinated by nine O atoms and one (OH) group. There is one Pb site occupied by Pb^{2+} coordinated by seven O atoms and one (OH) group in a very asymmetric arrangement that is characteristic of stereoactive lone-pair-electron behavior of Pb^{2+} . There is one Cu site occupied by Cu^{2+} coordinated by three O atoms, one (OH) group and one (H_2O) group in a square-pyramidal arrangement. The structure contains chains of face-sharing ($REE\phi_{10}$) polyhedra, which link to chains of ($Cu\phi_5$) and ($Pb\phi_7$) polyhedra by sharing edges and corners and through (CO_3) groups. Schuilingite-(Nd) is structurally related to gysinite-(Nd), another Nd-dominant REE carbonate mineral. The structure of gysinite-(Nd) also contains chains of face-sharing ($REE\phi_{10}$) polyhedra linked in a fashion similar to the analogous chains in schuilingite-(Nd). The space-group symmetry of gysinite-(Nd) is $Pm\bar{c}n$, a supergroup of $P2_1cn$. Loss of the center of symmetry in schuilingite-(Nd) is related to replacement of every second chain of ($REE\phi_{10}$) polyhedra by two ($Cu\phi_5$)–($Pb\phi_7$) chains of polyhedra.

Keywords: schuilingite-(Nd), crystal structure, carbonate, rare-earth element, gysinite-(Nd).

THE EFFECT OF DIFFERENCES IN COORDINATION ON ORDERING OF POLYVALENT CATIONS IN CLOSE-PACKED STRUCTURES: THE CRYSTAL STRUCTURE OF ARAKIITE AND COMPARISON WITH HEMATOLITE

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ABSTRACT

The crystal structure of arakiite, $(\text{Zn}, \text{Mn}^{2+}) (\text{Mn}^{2+}, \text{Mg})_{12} (\text{Fe}^{3+}, \text{Al})_2 (\text{As}^{3+}\text{O}_3) (\text{As}^{5+}\text{O}_4)_2 (\text{OH})_{23}$, monoclinic, space group Cc , a 14.236(2), b 8.206(1), c 24.225(4) Å, β 93.52(1)°, V 2824.0(7) Å³, $Z = 4$, has been solved by direct methods and has been refined to an R index of 5.6% based on 1825 observed (5sss) reflections measured with $\text{MoK}\alpha$ radiation. There are eighteen crystallographically distinct cation sites, and the site occupancies were assigned using the refined site-scattering values, the observed stereochemistry, and the unit formula derived by electron-microprobe analysis. There are three As sites; $As(1)$ and $As(3)$ are occupied by As^{5+} in tetrahedral coordination, and $As(2)$ is occupied by As^{3+} in triangular pyramidal coordination with a stereoactive lone-pair of electrons. There is one T site, $T(1)$, occupied by Zn and Mn^{2+} in tetrahedral coordination. There are fourteen M sites, all of which are octahedrally coordinated. The $M(4)$ site is occupied by Fe^{3+} , and the $M(14)$ site is occupied by $\text{Al} + \text{Fe}^{3+}$; there are six M sites occupied exclusively by Mn^{2+} , one M site occupied by $\text{Mn}^{2+} + \text{Mg}$, and five M sites occupied by $\text{Mg} + \text{Mn}^{2+}$. Bond-valence analysis shows that all anions not linked to As^{3+} or As^{5+} are OH groups. Arakiite has a close-packed packet structure with five anion layers that stack along the c -axis in the sequence $\cdot^{**}hch\cdot$ ($*$ = displaced from closest packed). There are five distinct polyhedral layers along the c axis, with general compositions $[\mathbf{G}_7(T\phi_4)\phi_{10}]$, $[\mathbf{G}_3M_4(\text{TO}_4)\phi_{10}]$, $[\mathbf{G}_4M_3(\text{TO}_3)\phi_{10}]$, $[\mathbf{G}_6M_1(\text{TO}_4)\phi_9]$, and $[\mathbf{G}M_6\phi_{14}]$. Four of the layers are topologically identical to the corresponding layers in the structure of hematolite; the fifth layer differs between the two structures: arakiite: $[\mathbf{G}_7(T\phi_4)\phi_{10}]$; hematolite: $[\mathbf{G}_6M\phi_{14}]$. The two structures may be written chemically as follows:

arakiite: $^{[4]}(\text{Zn}, \text{Mn}^{2+}) ^{[6]}(\text{Mn}^{2+}, \text{Mg})_{12} ^{[6]}(\text{Fe}^{3+}, \text{Al})_2 (\text{As}^{3+}\text{O}_3) (\text{As}^{5+}\text{O}_4)_2 (\text{OH})_{23}$

hematolite: $^{[6]}(\text{Mn}^{2+}) ^{[6]}(\text{Mn}^{2+}, \text{Mg})_{12} ^{[6]}(\text{Al}, \text{Fe}^{3+})_2 (\text{As}^{3+}\text{O}_3) (\text{As}^{5+}\text{O}_4)_2 (\text{OH})_{23}$

Arakiite and hematolite show distinct ordering patterns of M^{2+} and M^{3+} cations in topologically identical close-packed layers. The observed ordering can be related to incident bond-strength requirements of the anions; differences in ordering between the two structures result from the different coordinations of cations ($[4]$ in arakiite, $[6]$ in hematolite) in the $m = 0$ sheet.

Keywords: arakiite, crystal structure, arsenate, arsenite, hematolite, Långban, Sweden.

THE STRUCTURE OF MASUYITE, $\text{Pb}[(\text{UO}_2)_3\text{O}_3(\text{OH})_2](\text{H}_2\text{O})_3$, AND ITS RELATIONSHIP TO PROTASITE

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ABSTRACT

The structure of masuyite, $\text{Pb}[(\text{UO}_2)_3\text{O}_3(\text{OH})_2](\text{H}_2\text{O})_3$, $Z = 2$, monoclinic, a 12.241(3), b 7.008(2), c 6.983(2) Å, β 90.402(4)°, space group Pn , has been solved by direct methods and refined by full-matrix least-squares techniques to an agreement index (R) of 6.3 % for 2473 unique observed reflections ($|F_o| \geq 4\sigma_F$) collected using $\text{MoK}\alpha$ X-radiation and a CCD-based area detector. The structure contains three symmetrically distinct U^{6+} positions, each of which is occupied by nearly linear $(\text{UO}_2)^{2+}$ uranyl ions (Ur) that are coordinated by five additional anions arranged at the equatorial corners of pentagonal bipyramids capped by the O_{Ur} anions. The uranyl pentagonal bipyramids share edges to form α - U_3O_8 -type sheets that are parallel to (010). The interlayer contains two distinct Pb^{2+} sites as well as three H_2O groups. The Pb(1) site is close to fully occupied and is coordinated by seven atoms of O that are contained in the sheets of uranyl polyhedra, and three H_2O groups. The Pb(2) site is only ~12 % occupied and is coordinated by six atoms of O from the sheets of uranyl polyhedra and three H_2O groups. The structure of masuyite is closely related to that of protasite, but has an additional cation site in the interlayer.

Keywords: masuyite, uranyl mineral, protasite, structure determination.

ORLANDIITE, $\text{Pb}_3\text{Cl}_4(\text{SeO}_3)\cdot\text{H}_2\text{O}$, A NEW MINERAL SPECIES, AND AN ASSOCIATED LEAD–COPPER SELENITE CHLORIDE FROM THE BACCU LOCCI MINE, SARDINIA, ITALY

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ABSTRACT

Orlandiite, ideally $\text{Pb}_3\text{Cl}_4(\text{SeO}_3)\cdot\text{H}_2\text{O}$, is a new mineral species from a selenium-rich part of the oxidation zone at the old lead–arsenic mine of Baccu Locci, near Villaputzu, Sardinia, Italy. The mineral is colorless to white, translucent, brittle, has a vitreous to silky luster, and is not fluorescent in ultraviolet light. The calculated density is 5.66 g/cm^3 for the ideal formula, with $Z = 2$. The mineral is birefringent, with $n_{\text{meas.}} = n_{\text{calc.}} = 1.96 (\pm 0.1)$. An X-ray study carried out on a single crystal indicates a triclinic symmetry, space group $P\bar{1}$ (no. 2), a 8.136(3), b 8.430(6), c 9.233(7) Å, α 62.58(7), β 71.84(4), γ 75.13(4)°. The strongest six lines of the X-ray diffraction pattern [d in Å(I)(hkl)] are: 4.000(100)(002), 3.258(75)($\bar{1}21$), 3.188(75)($\bar{2}01$), 3.818(55)(201), 3.731(44)(122), and 2.103(40)(142). Orlandiite occurs as very small, elongate, tabular crystals up to 0.1 mm in length, colorless to white, in association with chalcocite, pseudobolite, anglesite, quartz and other selenites. The chemical formula has been determined from electron-microprobe data and a crystal-structure determination [final R index = 0.042 on 1226 reflections with $I > 3\sigma(I)$]. The structure contains two independent Pb atoms belonging to layers with idealized composition PbCl_2 ; a third disordered lead atom is located between these layers, together with a disordered SeO_3 group and the H_2O molecule. In most of the sites occupied by Cl atoms, there is a partial replacement by OH groups. Associated with orlandiite and chalcocite, and presently under study, is another new selenite, $\text{Pb}_4\text{CuCl}_3(\text{SeO}_3)_3(\text{OH})$, in the form of minute lemon-yellow aggregates of tiny platy crystals. The strongest six lines of the X-ray diffraction pattern for this phase [d in Å(I)(hkl)] are: 8.279(100)(010), 6.674(80)(110), 11.100(76)(001), 7.344(70)(100), 5.788(65)(101), and 6.036(60)($\bar{1}\bar{1}2$), which leads to the following unit-cell data: a 8.290(8), b 10.588(13), c 13.587(15) Å, α 124.47(8), β 110.60(9), γ 63.26(9)°, and $Z = 2$.

Keywords: orlandiite, new mineral species, selenites, Baccu Locci, Sardinia, Italy.

RARE SULFOSALTS FROM VULCANO, AEOLIAN ISLANDS, ITALY. II. MOZGOVAITE, $\text{PbBi}_4(\text{S,Se})_7$, A NEW MINERAL SPECIES

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ABSTRACT

Mozgovaite, a new mineral species, occurs as a high-temperature fumarole encrustation at La Fossa crater on Vulcano, Aeolian Islands, Italy. Associated minerals are bismuthinite, galenobismutite, cannizzarite and lillianite. The mineral occurs as tiny long prismatic crystals, up to 0.2 mm long and 0.02 mm across. The color is silvery grey, with a metallic luster. Bireflectance is weak, and pleochroism is absent. Anisotropism is rather strong, but without color effects. The measured microhardness, VHN_{10} , is 116. Electron-microprobe investigations of type mozgovaite gave Pb 13.90, Cd 0.26, Fe 0.02, Cu 0.01, Bi 64.79, As 0.05, S 16.91, Se 1.63, sum 97.57 wt %. The empirical formula, based on 12 atoms, is $(\text{Pb}_{0.87}\text{Cd}_{0.03})_{\Sigma 0.90}(\text{Bi}_{4.01}\text{As}_{0.01})_{\Sigma 4.02}(\text{S}_{6.82}\text{Se}_{0.27})_{\Sigma 7.09}$; the idealized formula is $\text{PbBi}_4(\text{S,Se})_7$. The strongest six lines of the powder-diffraction pattern [d in Å(I)(hkl)] are: 3.80(10)(280), 2.95(4B)(321), 2.34(4B)(0.16.0), 3.30(3)(400), 3.58(3)(141), and 3.40(2)(151). The unit-cell parameters of mozgovaite are: a 13.18(6), b 37.4(2), c 4.05(3) Å, $Z = 6$, space group $Bbmm$,

$D_{\text{calc}} = 6.26(6) \text{ g/cm}^3$. The mineral is named after Nadezhda Nikolaevna Mozgova, a Russian mineralogist (IGEM, Academy of Sciences, Moscow).

Keywords: mozgovaite, Pb–Bi sulfosalts, synthetic phase V, sublimate, fumaroles, Vulcano, Italy.

NEW Pd–Pb AND Pb–V OXIDES FROM A BONANZA-TYPE PGE-RICH, NEARLY BMS-FREE DEPOSIT IN THE PENIKAT LAYERED COMPLEX, FINLAND

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ABSTRACT

The Kirakkajuppura platinum-group-element (*PGE*) deposit, in the Penikat layered complex, Finland, is associated with the low-sulfide Sompujärvi *PGE* reef, located near the contact between ultramafic and gabbroic cumulates, close to the country rocks. The deposit is unique among other *PGE* deposits in layered intrusions as it displays, on relatively small scale, very high bulk-rock concentrations of *PGE* (up to ≥ 0.5 kg/t total *PGE*) along with a low content of S and Cr, e.g., ΣPGE 224 ppm, 108 ppm S and 0.8 wt.% Cr; $(Pd + Pt)/(Os + Ir + Ru) = 93.9$ and $Pd/Pt = 3.0$ (mean of four whole-rock analyses). The platinum-group minerals (*PGM*), predominantly Pt–Ni-poor vysotskite–braggite, zvyagintsevite and a Pd–Pb oxide, mainly occur in altered pyroxenite, among grains of Mg-rich actinolite and clinocllore, as unusually large veinlet-like or chain-like aggregates up to ~1 cm in length. In agreement with the whole-rock data, the *PGM* do not show a close relationship with base-metal sulfides (*BMS*) and accessory chromite, occur in virtually *BMS*-free chromite-poor samples, and are mainly responsible for the bulk-rock S. Unnamed Pd_9PbO_{10} [or $(Pd,Pb)O$] is the product of oxidation of the zvyagintsevite. It is anhydrous, is a very poor diffractor of X rays [the strongest two lines are 2.69(10vb) and 2.35(3) Å], and has a low reflectance (at 580 nm in air: R_1 20.2–20.7% and R_2 20.6–21.3%). Unnamed $Pb_4V_2O_9$ also occurs in the hydrous silicate association. The Kirakkajuppura *PGE* deposit cannot have formed as a result of the collection of the *PGE* by a magmatic sulfide liquid *in situ*. The late-stage *PGM*, responsible for the high *PGE* concentration in this deposit, precipitated from volatile-rich hydrothermal fluids.

Keywords: platinum-group elements, platinum-group minerals, Pd–Pb oxide, Pb–V oxide, unnamed minerals, mafic-ultramafic rocks, Kirakkajuppura *PGE* deposit, Penikat complex, layered intrusion, Fennoscandian Shield, Finland.

OCCURRENCE AND DISTRIBUTION OF INVISIBLE GOLD IN THE SHEWUSHAN SUPERGENE GOLD DEPOSIT, SOUTHEASTERN HUBEI, CHINA

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ABSTRACT

The Shewushan gold deposit, eastern Hubei, China, hosted in weathered mantle above the Shewushan thrust zone, is probably an example of a type of deposit where all the ore-grade gold is related to surficial weathering processes of a previously uneconomic gold deposit. Electron-probe micro-analysis (EPMA) and analytical electron microscopy (AEM), optical microscopy, and chemical dissolution were done to determine the occurrence and distribution of gold in the ore. The optical microscopy study demonstrates that gold is invisible in ordinary light. Fire assay yielded 4.34 g/t Au for clay-mineral separates. The AEM analysis showed that gold associated with clay minerals occurs as submicrometric particles at the rim of clay-mineral grains. EPMA data showed that gold in goethite occurs as micrometric granules of native gold or as an adsorbed phase (or both). The gold content of other minerals, such as quartz, “chalcedony” and barite, is generally below the detection limit of EPMA (0.05%). The characterization of invisible Au in this supergene gold deposit is beneficial to the design of a metallurgical process for Au recovery and to our understanding of the transport and accumulation of Au during the process of weathering under supergene conditions.

Keywords: occurrence, distribution, gold, invisible gold, clay minerals, goethite, electron-probe micro-analysis, analytical electron microscopy, Shewushan deposit, Hubei, China.