

GEOLOGICAL SETTING AND PETROGENESIS OF SYMMETRICALLY ZONED,
MIAROLITIC GRANITIC PEGMATITES AT STAK NALA, NANGA PARBAT –
HARAMOSH MASSIF, NORTHERN PAKISTAN

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ABSTRACT

Miarolitic granitic pegmatites in the Stak valley in the northeast part of the Nanga Parbat – Haramosh Massif, in northern Pakistan, locally contain economic quantities of bi- and tricolored tourmaline. The pegmatites form flat-lying sills that range from less than 1 m to more than 3 m thick and show symmetrical internal zonation. A narrow outer or border zone of medium to coarse-grained oligoclase – K-feldspar – quartz grades inward to a very coarse-grained wall zone characterized by K-feldspar – oligoclase – quartz – schorl tourmaline. Radiating sprays of schorl and flaring megacrysts of K-feldspar (intermediate microcline) point inward, indicating progressive crystallization toward the core. The core zone consists of variable mixtures of blocky K-feldspar (intermediate microcline), oligoclase, quartz, and sparse schorl or elbaite, with local bodies of sodic aplite and crystal-lined pockets. Minor spessartine–almandine garnet and löllingite are disseminated throughout the pegmatite, but were not observed in the pockets. The pockets contain well-formed crystals of albite, quartz, K-feldspar (maximum microcline \pm orthoclase overgrowths), schorl–elbaite tourmaline, muscovite or lepidolite, topaz, and small amounts of other minerals. Elbaite is color-zoned from core to rim: green (Fe²⁺- and Mn²⁺-bearing), colorless (Mn²⁺-bearing), and light pink (trace Mn³⁺). Within ~15 cm of the pegmatites, the granitic gneiss wallrock is bleached owing to conversion of biotite to muscovite, with local quartz and albite added. Schorl is disseminated through the altered gneiss, and veins of schorl with bleached selvages locally traverse the wallrock up to 1 m from the pegmatite contact. The schorl veins can be traced into the outer part of the wall zone, which suggests that they formed from aqueous fluids derived during early saturation of the pegmatite-forming leucogranitic magma rich in H₂O, F, B, and Li. Progressive crystallization resulted in a late-stage sodic magma and abundant aqueous fluids. Two late stages of volatile escape are recognized: the first stage caused pressure-quenching of the last magma, which produced aplite and caused albitization (An₃ to An₈) of earlier crystallized K-feldspar and oligoclase. A second stage of volatiles, released during the rupture of miarolitic cavities, produced platy albite ("cleavelandite", An₁) locally associated with F-rich muscovite and elbaite. Albitization is likely due to cooling of alkali-fluoride-dominated fluids at

less than 2 kbar pressure. The pegmatites are derived from Himalayan leucogranitic magma emplaced prior to 5 Ma into granulitic gneiss that was at 300° to 550°C and 1.5 to 2 kbar. The pegmatites were emplaced during uplift of the Haramosh Massif, since they cross-cut ductile normal faults but are cut by brittle normal faults. Economically important pink tourmaline mineralization formed in miarolitic pockets concentrated near the crest of a broad antiform, as a result of trapping of late magmatic aqueous fluids that were Fe-poor owing to the prior crystallization of schorl.

Keywords: granitic pegmatite, volatile saturation, miarolitic cavity, elbaite tourmaline, hydrothermal alteration, albitization, Stak Nala, Nanga Parbat – Haramosh massif, Pakistan.

THE MAFIC MINERALS OF THE FALCON ISLAND ULTRAPOTASSIC PLUTON, LAKE OF THE WOODS, ONTARIO: PROGRESSIVE REDUCTION DURING FRACTIONATION

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ABSTRACT

The Falcon Island complex is an ultrapotassic pluton with a U–Pb age of 2695 ± 3 Ma intruding the Lake of the Woods greenstone belt in the Wabigoon Subprovince of the Superior Province, in western Ontario. It consists of nepheline-bearing alkali-feldspar syenite and alkali feldspar melasyenite with lesser amounts of clinopyroxenite, monzodiorite, and peraluminous alkali feldspar syenite. The magma evolved with increasing P(H₂O), as indicated by clinopyroxene cores mantled by hornblende, and hypersolvus perthitic alkali feldspar phenocrysts followed by subsolvus interstitial plagioclase, alkali feldspar and nepheline. An "aegirine-enrichment trend" is evident in the clinopyroxene as progressive depletion in Mg and Ca, and enrichment in Fe and Na (both as zoning in individual grains and in the successively fractionated units). Decreasing $\text{Fe}^{3+}/(\text{Fe}^{2+} + \text{Fe}^{3+})$ accompanied by increasing Fe/(Fe + Mg), Ti, and ^{IV}Al contents of the biotite of the fractionated rock units indicates progressive reduction and Al enrichment of the magma with fractionation. A spatial and genetic linkage of gold mineralization to oxidized alkaline intrusions has been hypothesised on the basis of mineral chemical studies from the Abitibi Subprovince. The lack of spatially associated gold mineralization with the progressively reduced Falcon Island pluton, despite its proximity to a potentially favorable deformation zone, supports this hypothesis.

Keywords: Falcon Island pluton, Wabigoon belt, syenite, clinopyroxene, amphibole, biotite, feldspars, fractional crystallization, ultrapotassic suite, Lake of the Woods greenstone belt, Ontario.

FELDSPAR THERMOMETRY: A VALUABLE TOOL FOR DECIPHERING THE THERMAL HISTORY OF GRANULITE-FACIES ROCKS, AS ILLUSTRATED WITH METAPELITES FROM SRI LANKA

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ABSTRACT

Two-feldspar geothermometry is applied to granulite-facies metapelites from the Highland Complex of Sri Lanka, for which very high peak temperatures of metamorphism have been inferred. Two-feldspar thermometry can be applied, even where only one feldspar has preserved its original bulk-composition in terms of Al–Si content, in spite of or because of unmixing to perthite or antiperthite. Different methods of integration of the unmixed feldspars to get the original bulk-composition are evaluated. Several types of feldspar assemblages are distinguished: (1) disequilibrium and near-equilibrium perthite – plagioclase pairs (several generations), (2) disequilibrium antiperthite – perthite pairs, (3) single mesoperthites, (4) near-equilibrium antiperthite–mesoperthite pairs. The highest temperatures above 900 °C are derived from antiperthite porphyroclasts with evenly spaced exsolution lamellae and rods, from antiperthite – mesoperthite pairs, and from perthite inclusions in garnet porphyroclasts. The causes for the preservation of ternary feldspar compositions are discussed. Feldspar recrystallization in response to strong deformation is related to thrusting of the Highland Complex onto the Vijayan Complex. It occurred at about 830–900 °C. In the main part of the Highland Complex, the feldspars recrystallized at *ca.* 680–760 °C. Mylonitization along the Digana shear zone took place at about 710 °C. Late retrograde recrystallization or growth of feldspar rims occurred in the range 460–590 °C. Two-feldspar geothermometry combined with published geochronological data reveal new insights in the metamorphic evolution of the Highland Complex of Sri Lanka.

Keywords: feldspar thermometry, antiperthite, perthite, mesoperthite, metapelites, granulite facies, metamorphic evolution, Sri Lanka.

IDENTIFICATION OF NORMAL AND ANOMALOUS COMPOSITIONS OF MINERALS BY ELECTRON-MICROPROBE ANALYSIS: K-RICH FELDSPAR AS A CASE STUDY

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ABSTRACT

The precision of electron-microprobe (EMP) measurements at a 4σ level of confidence is about 1%. By using internally consistent standards with compositions compatible with stoichiometries of the structural formulae, minerals with a generally similar matrix may be analyzed with $\leq 2\%$ accuracy. Systematic analytical error of a standard may be greatly reduced by examination of the results of analysis of closely related unknown minerals. If a standard is compositionally and structurally well characterized, the accuracy of analysis of samples of near-identical composition may then approach 1% absolute. The bulk of the results, which give the expected stoichiometry of the structure, may be classified as normal. Anomalous measurements, which do not conform to ideal stoichiometry of feldspar, were used to identify analytical overlap with hematite micro-inclusions, light-element substitution, and a compositional trend toward $\square\text{Si}_4\text{O}_8$ in adularia from granitic pegmatites.

Keywords: electron-microprobe analysis, framework silicates, alkali feldspar, Eifel sanidine, adularia, granitic pegmatite.

CLINOPYROXENE FROM LIPARI: COMPARISON WITH ANALOGUES FROM OTHER AEOLIAN ISLANDS, ITALY

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ABSTRACT

Clinopyroxene phenocrysts from the volcanic rocks of Lipari, one of the Aeolian Islands (Italy), were characterized by single-crystal X-ray diffraction and electron-microprobe analysis. They form three groups, related to different volcanic cycles. Although there is no evidence of tholeiitic rocks in the archipelago, the structural framework of these clinopyroxenes is close to those of clinopyroxene from subalkaline basalts of tholeiitic affinity. This feature may be ascribed to contamination of the magma by older gabbros in the lower crust, or to crystallization from an early magma of tholeiitic composition. Comparisons with analogues from other Aeolian Islands (Vulcano, Salina, Filicudi and Stromboli) highlight the fact that the Lipari clinopyroxene are low-pressure phenocrysts.

Keywords: clinopyroxene, crystal chemistry, volcanic rocks, pressure of crystallization, subalkaline, Lipari, Aeolian Islands, Italy.

LATRAPPITE: A RE-INVESTIGATION

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ABSTRACT

Compositional data are presented for latrappite and other niobium-rich perovskite-group minerals from the Oka, Kaiserstuhl and Magnet Cove carbonatite complexes. Latrappite is shown to be a member of a continuous solid-solution involving CaTiO_3 , NaNbO_3 , $\text{Ca}_2\text{NbFe}^{3+}\text{O}_6$ and $\text{Ca}_2\text{Nb}_2\text{O}_7$. ^{57}Fe Mössbauer spectrometry demonstrates that only ferric iron is present in latrappite. The crystal structure of latrappite, determined by Rietveld analysis, is similar to that of CaTiO_3 perovskite. It differs in that replacement of Ti by Nb and Fe^{3+} results in greater distortion and tilting of the TiO_6 framework polyhedra relative to CaTiO_3 . Revised unit-cell parameters of latrappite are: a 5.4479(3), b 5.5259(3), c 7.7575(5) Å, V 233.54 Å³, space group $Pbnm$.

Keywords: perovskite, latrappite, Rietveld analysis, crystal structure, Mössbauer spectrometry, electron microscopy.

COMPOSITION OF CHROMITE IN THE UPPER CHROMITITE, MUSKOX LAYERED INTRUSION, NORTHWEST TERRITORIES

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ABSTRACT

The texture, mineralogy and composition of chromite in the upper chromitite of the Muskox intrusion, in the Northwest Territories, have been studied in two 0.5-meter sections of drill core. The principal rock-type is an orthopyroxenite that contains cumulus olivine, orthopyroxene and chromite, and the intercumulus minerals clinopyroxene and plagioclase. The minor minerals ilmenite and biotite are found, together with a number of accessory minerals, in pockets that are interpreted as sites of late intercumulus melt. The chromitite seam is up to 10 cm thick and contains chromite with a narrow range in composition: $0.64 < \text{Cr}/(\text{Cr} + \text{Al}) < 0.74$, $0.62 < \text{Fe}^{2+}/(\text{Fe}^{2+} + \text{Mg}) < 0.69$, and $0.18 < \text{Fe}^{3+}/(\text{Fe}^{3+} + \text{Al} + \text{Cr}) < 0.26$. The average composition of chromite in the chromitite, and the olivine and orthopyroxene in the orthopyroxenite, were used to calculate a temperature of 1146°C and $\log f(\text{O}_2) = -9.1$. The disseminated chromite in the orthopyroxenite shows a much greater range in composition and increases in $\text{Fe}^{2+}/(\text{Fe}^{2+} + \text{Mg})$, $\text{Fe}^{3+}/(\text{Fe}^{3+} + \text{Al} + \text{Cr})$, Ti and Ni with stratigraphic height above the massive chromitite. The chromite in the Muskox chromitite is significantly higher in Fe^{3+} , Ti and $\text{Fe}^{2+}/(\text{Fe}^{2+} + \text{Mg})$ than chromite in the Bushveld, Stillwater and Great Dyke chromitites; furthermore, the Muskox chromitites formed much higher in the stratigraphic section of the layered series than in these other intrusions. The Muskox chromitites are considered to have formed late in the magmatic history of the intrusion as a result of mixing of a fractionated magma with a more primitive magma and a component due to wall-rock assimilation.

Keywords: chromite, chromitite, orthopyroxene, layered intrusions, Muskox, Northwest Territories.

CHLORITOID INCLUSIONS IN PYRITE FROM NAVAJÚN, SPAIN

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ABSTRACT

Almost pure Fe end-member chloritoid was identified as the major included phase in large cubes of pyrite from Navajún, Logroño, Spain. The silicates in the pyrite matrix as well as isolated mineral separates were analyzed by electron microprobe, X-ray diffraction, and Mössbauer spectroscopy. Mössbauer spectra taken at room temperature and at 77 Kelvin show a superposition of an Fe²⁺ doublet and at least one Fe³⁺ doublet. The chloritoid from one of the pyrite cubes analyzed is more oxidized than that in the two other cubes. Mössbauer data give some evidence that this may be due to the presence of Fe³⁺ in sites normally occupied by Fe²⁺. In all samples, significant effects due to preferred orientation have been observed in both the X-ray and Mössbauer spectra.

Keywords: chloritoid, pyrite, Mössbauer spectroscopy, Navajún, Logroño, Spain.

LOW-TEMPERATURE FAYALITE, GREENALITE, AND MINNESOTAITE FROM THE
OVERLOOK GOLD DEPOSIT, WASHINGTON: PHASE RELATIONS IN THE SYSTEM
FeO–SiO₂–H₂O

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ABSTRACT

At the Overlook gold mine in northeastern Washington, a fayalite-bearing assemblage of iron silicates, magnetite, and pyrrhotite, plus quartz and calcite, formed during alteration of a Permian volcanogenic, carbonate-rich, massive magnetite–sulfide seafloor deposit. The temperature of fluid inclusion homogenization, oxygen isotope ratios, and phase equilibrium calculations constrain the temperature of the fayalite-forming environment to approximately 300°C. The fayalite is close to end-member composition, Fa_{95–98}, and the greenalite and minnesotaite are correspondingly Fe-rich. No grunerite has been found. The paragenetic sequence fayalite → greenalite → minnesotaite → quartz represents infiltration at approximately 300°C of an initially very reducing, Fe-rich hydrothermal fluid that became progressively more SiO₂-rich. Provisional thermodynamic data for greenalite are presented, and these are used to construct P–T–*a*(SiO₂) phase diagrams for the system FeO–SiO₂–H₂O. Phase relations in this system differ topologically from those in the analogue system MgO–SiO₂–H₂O by virtue of the H₂O-conserved reaction: talc + olivine = MgFe-amphibole + serpentine, which proceeds from left to right with an increase in Fe:Mg ratio of the system. One sample contains in addition to greenalite an iron-dominant serpentine with ideal serpentine stoichiometry, Fe : Si = 3 : 2.

Keywords: hydrothermal fayalite, greenalite, minnesotaite, FMSH system, Overlook gold mine, Washington.

MODULATED CRYSTAL STRUCTURES OF GREENALITE AND CARYOPILITE: A SYSTEM WITH LONG-RANGE, IN-PLANE STRUCTURAL DISORDER IN THE TETRAHEDRA SHEET

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ABSTRACT

High-resolution transmission electron microscope (TEM) images confirm that greenalite and caryopilite are modulated 1:1 phyllosilicates. The octahedrally coordinated Fe (greenalite) and Mn (caryopilite) form trioctahedral sheets. Six-member rings of tetrahedra link to form triangular islands four or five tetrahedra across, with each island coordinating to one octahedral sheet. Adjacent islands are inverted and link to the neighboring octahedral sheet, which results in a triply-intersecting corrugation for the tetrahedral sheet. Islands vary in numbers of tetrahedra about a mean dictated by the octahedral sheet dimension. Island separations range about a mean distance within the X - Y plane, with island alignment fluctuating as a function of lattice vectors defined by the octahedral sheet. The tetrahedra thus show limited short-range order (spanning to five octahedra), but long-range disorder. Linkages of tetrahedra between islands are apparently completely disordered. Because of this disorder, there is no definable unit-cell. Fourier calculations involving non-repeating structures cannot use unit-cell fractional coordinates and Miller indices. We calculated diffraction patterns by finding the real-space coordinates of every atom in the model relative to a defined origin. The reciprocal space variable, d^* , is sampled at intervals of 0.005 Å to build the continuous Fourier transform of the model. Discrete polytypes of $1T$ and $1M$ for greenalite and caryopilite, respectively, were identified. Where grains contain mixtures, the relative abundance of each polytype is related to composition, with the dominant polytype based on minimizing misfit between the sheets of octahedra and of tetrahedra. Stacking in greenalite and caryopilite is defined by the relative positions of adjacent octahedral sheets and, therefore, limits on the displacements of neighboring domains of silicate rings within (001) are possible. Domain boundary linkages, however, cannot be determined precisely by using either diffraction or imaging data.

Keywords: greenalite, caryopilite, serpentines, modulated structures, superstructure, phyllosilicates, polytypism, Fourier synthesis of disordered structures, electron diffraction.

CHARACTERIZATION OF OH–F SHORT-RANGE ORDER IN POTASSIUM-FLUOR-RICHTERITE BY INFRARED SPECTROSCOPY IN THE OH-STRETCHING REGION

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ABSTRACT

The infrared spectrum of a sample of potassium-fluor-richterite (PFR) is compared with that of a synthetic “potassium-richterite” having a similar OH–F content. The PFR spectrum shows an additional absorption band with respect to the synthetic sample, and this is assigned to a configuration involving ^[71]Al. The spectra show that there is strong short-range order of OH in the structure of PFR, that involves coupling between H and (Si,Al) rings of tetrahedra in response to the bond-valence requirements on the bridging atoms of oxygen in Al–O–Si dimers of tetrahedra.

Keywords: potassium-fluor-richterite, FTIR spectroscopy, O–H-stretching region, OH–F short-range order.

THE STRUCTURE OF RICHTETITE, A RARE LEAD URANYL OXIDE HYDRATE

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ABSTRACT

The structure of richtetite, approximate formula $M_x\text{Pb}_{8.57}[(\text{UO}_2)_{18}\text{O}_{18}(\text{OH})_{12}]_2(\text{H}_2\text{O})_{41}$, $Z = 1$, triclinic, a 20.9391(3), b 12.1000(2), c 16.3450(3) Å, α 103.87(1), β 115.37(1), γ 90.27(1)°, V 3605.2 Å³, space group $P1$, has been solved by direct methods and refined by full-matrix least-squares techniques to an agreement factor (R) of 8.9% and a goodness-of-fit (S) of 1.79 using 12,383 unique observed reflections ($|F_o| > 4\sigma_F$) collected with MoK α X-radiation and a CCD (charge-coupled device) area detector. The structure contains 36 unique U⁶⁺ positions, each of which is part of a near-linear (U⁶⁺O₂)²⁺ uranyl ion that is further coordinated by five (O, OH⁻) anions, forming pentagonal bipyramids. The uranyl polyhedra share edges to form symmetrically distinct but topologically identical α -U₃O₈-type sheets at $z \approx 0.25$ and $z \approx 0.75$. Although α -U₃O₈-type sheets of uranyl polyhedra occur in several structures, the richtetite sheets are unique in their arrangement of OH⁻ anions. There are 13 partially occupied unique Pb²⁺ sites, two octahedrally coordinated M sites that may contain Fe³⁺ or other cations, and 41 unique H₂O groups in two distinct interlayers at $z \approx 0$ and $z \approx 0.5$. Both the Pb²⁺ and M cations link to uranyl-ion O-atoms from adjacent sheets, and thus provide linkage of the sheets to the interlayer constituents. An extensive network of H bonds provides additional linkage.

Keywords: richtetite, uranyl mineral, uranium, structure determination, lead uranyl oxide hydrate.

KENHSUITE, γ -Hg₃S₂Cl₂, A NEW MINERAL SPECIES FROM THE McDERMITT MERCURY DEPOSIT, HUMBOLDT COUNTY, NEVADA

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ABSTRACT

Kenhsuite, γ -Hg₃S₂Cl₂, a new mineral species, occurs with cinnabar and mercury sulfohalide minerals at the McDermitt mercury mine, Humboldt County, Nevada, where it is associated with the alpha form, corderoite, α -Hg₃S₂Cl₂. Kenhsuite crystals, $1 \times 10 \mu\text{m}$ long, are dispersed along fractures in altered tuffaceous lacustrine rocks. Kenhsuite is orthorhombic, with possible space-groups *Ammm*, *A2mm*, *Am2m*, *Amm2*, or *A222*; *a* 9.332(5), *b* 16.82(2), *c* 9.108(5) Å; *V* 1429.63 Å³, *a*:*b*:*c* = 0.5548:1.0:0.5415, and *Z* = 8. The strongest four peaks in the X-ray powder-diffraction pattern [*d* in Å(*I*)(*hkl*)] are 2.58(100)(242), 3.65(90)(122), 3.11(51)(300), and 2.60(49)(331). Color and streak are canary yellow. The mineral blackens on exposure to sunlight. Kenhsuite is transparent, with a glassy luster; it has a Mohs hardness of 2–3 and a conchoidal and hackly fracture. It fluoresces red and red-orange under 366 nm ultraviolet radiation. The measured density is 6.83 (5) g/cm³, and the calculated density, 6.87 g/cm³. Kenhsuite is biaxial (+), with $2V_z$ greater than 70°, and index of refraction 2.25 ± 0.01 . It has pleochroic colors that are weak pale yellow to greenish yellow. In reflected light, kenhsuite has medium to low reflectance, estimated at about 15%, and is white with abundant bright canary yellow to palest yellow-white internal reflections. Its polishing hardness is about the same as cinnabar (soft, 2–2.5). Kenhsuite formed later than cinnabar and corderoite, and possibly, in part simultaneously with corderoite. The mineral is named after Dr. Kenneth Jinghwa Hsu, Professor Emeritus, Swiss Federal Institute of Technology, Zurich, Switzerland.

Keywords: kenhsuite, corderoite, mercury, sulfochloride, polymorphism, McDermitt, Nevada.

SOLID SOLUTION IN SYNTHETIC ZINKENITE, ROBINSONITE AND MENEGHINITE IN THE SYSTEM $\text{Cu}_2\text{S-PbS-Sb}_2\text{S}_3$

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ABSTRACT

The extent of solid solution in zinkenite, robinsonite and meneghinite has been determined from electron-microprobe-established compositions of their synthetic analogs in pertinent assemblages in the course of a phase-equilibrium study of the system $\text{Cu}_2\text{S-PbS-Sb}_2\text{S}_3$. All the three solid-solution fields are elongate more or less parallel to the $\text{PbS-Sb}_2\text{S}_3$ binary join, and are relatively broader at their PbS-rich ends. The positions of the PbS-rich ends are practically insensitive to variations in temperature. Robinsonite and meneghinite are not stable at 300°C. Plots of molar proportions of Sb_2S_3 versus PbS suggest a common scheme of substitution, $3\text{Pb}^{2+} = 2\text{Sb}^{3+}$. In PbS-rich compositions of the solid solutions, the proportion of Cu is substantial, and Cu must be incorporated on the left-hand side of the substitution scheme. Natural compositions of meneghinite cluster at one point in the $\text{Cu}_2\text{S-PbS-Sb}_2\text{S}_3$ ternary system, but zinkenite and robinsonite have variable compositions. The most appropriate formula for zinkenite appears to be $6\text{PbS}\cdot 7\text{Sb}_2\text{S}_3$. Likewise, $4\text{PbS}\cdot 3\text{Sb}_2\text{S}_3$ is the preferred formula for robinsonite.

Keywords: solid solution, zinkenite, robinsonite, meneghinite, substitution scheme, phase-equilibrium study.

COMPOSITIONAL CONTROLS ON PHASE-TRANSITION TEMPERATURES IN BORNITE: A DIFFERENTIAL SCANNING CALORIMETRY STUDY

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ABSTRACT

Structural phase transitions in bornite (Cu_5FeS_4) are associated with distinctive thermal anomalies. We investigated variations in the phase-transition temperatures of bornite using differential scanning calorimetry (DSC). The composition of 48 samples of natural and synthetic low bornite was determined using an electron microprobe operating in WDS mode. Temperatures of the low–intermediate and intermediate–high transitions of these samples were then determined by performing heating and cooling DSC scans over the range 50–300°C. Heating-run peaks of thermal anomalies associated with the low–intermediate transition varied between 197–207°C in natural samples and 154–201°C in synthetic samples of bornite. The thermal anomalies associated with the intermediate–high transition occur between 259 and 273°C in natural samples, and between 239 and 271°C in synthetic bornite. The marked variations in temperatures of the intermediate–high transition are linearly related to the Fe content and the Cu:Fe ratio. No such relationships are associated with the low–intermediate transition, implying the existence of fundamental differences in the mechanisms of the two transitions. On average, synthetic samples of bornite underwent the low–intermediate transition at lower temperatures than natural samples, this phenomenon being attributed to the possible presence of a larger population of quenched-in vacancies and the lower concentration of trace impurities in synthetic bornite.

Keywords: bornite, differential scanning calorimetry, copper iron sulfide, Cu_5FeS_4 , phase transitions.