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Archaeo-environmental characterization of the Arvernian gold mines of Auvergne (France)

Frédéric Trément, Jacqueline Argant, Élise Brémon, Hervé Cubizolle,
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CONTENTS

[No. 494, FEBRUARY 2012]

T. LLORENS and M. C. MORO: Fe-Mn phosphate associations as indicators of the magmatic-hydrothermal and supergene evolution of the Jálama batholith in the Navasfrías Sn-W District, Salamanca, Spain	1
W. A. CRICHTON, J. B. PARISE, H. MÜLLER, J. BREGER, W. G. MARSHALL and M. D. WELCH: Synthesis and structure of magnesium hydroxide fluoride, Mg(OH)F: a topological intermediate between brucite- and rutile-type structures	25
A. V. STEPANOV, G. K. BEKENOVA, V. L. LEVIN and F. C. HAWTHORNE: Natrotitanite, ideally $(\text{Na}_{0.5}\text{Y}_{0.5})\text{Ti}(\text{SiO}_4)\text{O}$, a new mineral from the Verkhnée Espe deposit, Akjailyautas mountains, Eastern Kazakhstan district, Kazakhstan: description and crystal structure	37
F. C. HAWTHORNE, M. A. COOPER, Y. A. ABDU, N. A. BALL, M. E. BACK and K. T. TAIT: Davidlloydite, ideally $\text{Zn}_3(\text{AsO}_4)_2(\text{H}_2\text{O})_4$, a new arsenate mineral from the Tsumeb mine, Otjikoto (Oshikoto) region, Namibia: description and crystal structure	45
M. S. RUMSEY, S. V. KRIVOVICHEV, O. I. SIDRA, C. A. KIRK, C. J. STANLEY and J. SPRATT: Rickturnerite, $\text{Pb}_7\text{O}_4[\text{Mg}(\text{OH})_4](\text{OH})\text{Cl}_3$, a complex new lead oxychloride mineral	59
D. ATENCIO, A. C. ROBERTS, M. A. COOPER, L. A. D. MENEZES FILHO, J. M. V. COUTINHO, J. A. R. STIRLING, K. E. VENANCE, N. A. BALL, E. MOFFATT, M. L. S. C. CHAVES, P. R. G. BRANDÃO and A. W. ROMANO: Carlosbarbosite, ideally $(\text{UO}_2)_2\text{Nb}_2\text{O}_6(\text{OH})_2 \cdot 2\text{H}_2\text{O}$, a new hydrated uranyl niobate mineral with tunnels from Jaguaráçu, Minas Gerais, Brazil: description and crystal structure	75
A. Y. BORISOVA, R. THOMAS, S. SALVI, F. CANDAUDAP, A. LANZANOVA and J. CHEMELEFF: Tin and associated metal and metalloid geochemistry by femtosecond LA-ICP-QMS microanalysis of pegmatite–leucogranite melt and fluid inclusions: new evidence for melt–melt–fluid immiscibility	91
J. GÖTZE, L. NASDALA, U. KEMPE and E. LIBOWITZKY: The origin of black colouration in onyx agate from Mali	115
A. YU. LIKHACHEVA, S. V. RASHCHENKO and YU. V. SERYOTKIN: The deformation mechanism of a pressure-induced phase transition in dehydrated analcime	129
S. V. TITKOV, S. V. KRIVOVICHEV and N. I. ORGANOVA: Plastic deformation of natural diamonds by twinning: evidence from X-ray diffraction studies	143
<i>CNMNC Newsletter 12</i>	
P. A. WILLIAMS, F. HATERT, M. PASERO and S. J. MILLS: New minerals and nomenclature modifications approved in 2011	151
C. M. B. HENDERSON and W. J. PIEROZYNSKI: An experimental study of Sr, Ba and Rb partitioning between alkali feldspar and silicate liquid in the system nepheline–kalsilite–quartz at 0.1 GPa $P(\text{H}_2\text{O})$: a revisitiation and reassessment	157
G. BALASSONE, F. BELLATRECCIA, A. MORMONE, C. BIAGIONI, M. PASERO, C. PETTI, N. MONDILLO and G. FAMELI: Sodalite-group minerals from the Somma–Vesuvius volcanic complex, Italy: a case study of K-feldspar-rich xenoliths	191
D. MARSHALL, V. PARDIEU, L. LOUGHREY, P. JONES and G. XUE: Conditions for emerald formation at Davdar, China: fluid inclusion, trace element and stable isotope studies	213

[No. 495, APRIL 2012]

Continuing the Carbonatite Controversy	
H. DOWNES, F. WALL, A. DEMÉNY and C. SZABÓ: Preface	255
A. R. WOOLLEY and D. K. BAILEY: The crucial role of lithospheric structure in the generation and release of carbonatites: geological evidence	259
D. K. BAILEY and S. KEARNS: New forms of abundant carbonatite–silicate volcanism: recognition criteria and further target locations	271

CONTENTS

K. R. MOORE: Experimental study in the Na ₂ O–CaO–MgO–Al ₂ O ₃ –SiO ₂ –CO ₂ system at 3 GPa: the effect of sodium on mantle melting to carbonate-rich liquids and implications for the petrogenesis of silicocarbonatites	285
C. DE IGNACIO, M. MUÑOZ and J. SAGREDO: Carbonatites and associated nephelinites from São Vicente, Cape Verde Islands	311
A. E. BRADY and K. R. MOORE: A mantle-derived dolomite silicocarbonatite from the southwest coast of Ireland	357
A. C. J. M. BAMBI, A. COSTANZO, A. O. GONÇALVES and J. C. MELGAREJO: Tracing the chemical evolution of primary pyrochlore from plutonic to volcanic carbonatites: the role of fluorine	377
L. TORRÓ, C. VILLANOVA, M. CASTILLO, M. CAMPENY, A. O. GONÇALVES and J. C. MELGAREJO: Niobium and rare earth minerals from the Virulundo carbonatite, Namibe, Angola	393
I. P. SOLOVOVA and A. V. GIRNIS: Silicate–carbonate liquid immiscibility and crystallization of carbonate and K-rich basaltic magma: insights from melt and fluid inclusions	411
Book review	441

[No. 496, JUNE 2012]

J. PLÁŠIL, K. FEJFAROVÁ, R. SKÁLA, R. ŠKODA, N. MEISSER, J. HLOUŠEK, I. ČISAŘOVÁ, M. DUŠEK, F. VESELOVSK, J. ČEJKA, J. SEJKORA and P. ONDRUŠ: The crystal chemistry of the uranyl carbonate mineral grimselite, (K,Na) ₃ Na[(UO ₂)(CO ₃) ₃](H ₂ O), from Jáchymov, Czech Republic	443
T. ARMBRUSTER, B. LAZIC, I. O. GALUSKINA, E. V. GALUSKIN, E. GNOS, K. M. MARZEC and V. M. GAZEEV: Trabzonite, Ca ₄ [Si ₃ O ₉ (OH)]OH: crystal structure, revised formula, new occurrence and relation to killalaite	455
F. CÁMARA, E. SOKOLOVA and F. C. HAWTHORNE: Kazanskyite, Ba□TiNbNa ₃ Ti(Si ₂ O ₇) ₂ O ₂ (OH) ₂ (H ₂ O) ₄ , a Group-III Ti-disilicate mineral from the Khibiny alkaline massif, Kola Peninsula, Russia: description and crystal structure	473
U. KOLITSCH, S. MERLINO and D. HOLTSTAM: Molybdophyllite: crystal chemistry, crystal structure, OD character and modular relationships with britvinitite	493
A. R. KAMPF, S. J. MILLS, M. S. RUMSEY, J. SPRATT and G. FAVREAU: The crystal structure determination and redefinition of matulaite, Fe ³⁺ Al ₇ (PO ₄) ₄ (PO ₃ OH) ₂ (OH) ₈ (H ₂ O) ₈ ·8H ₂ O	517
R. MACDONALD, B. BAGIŃSKI, P. KARTASHOV, D. ZOZULYA and P. DZIERZANOWSKI: Chevkinite-group minerals from Russia and Mongolia: new compositional data from metasomatites and ore deposits	535
L. BINDI, R. T. DOWNS, P. G. SPRY, W. W. PINCH and S. MENCHETTI: A chemical and structural re-examination of fettelite samples from the type locality, Odenwald, southwest Germany	551
R. L. KIMBER, C. BOOTHMAN, P. PURDIE, F. R. LIVENS and J. R. LLOYD: Biogeochemical behaviour of plutonium during anoxic biostimulation of contaminated sediments	567
H. ROLLINSON, J. ADETUNJI, A. A. YOUSIF and A. M. GISMELSEED: New Mössbauer measurements of Fe ³⁺ /ΣFe in chromites from the mantle section of the Oman ophiolite: evidence for the oxidation of the sub-oceanic mantle	579
O. I. SHIDRA, N. V. CHUKANOV, I. V. PEKOV, S. V. KRIVOVICHEV, A. MAGGANAS, A. KATERINOPOULOS and P. VOUDOURIS: Pb ₂ (AsO ₂ OH)Cl ₂ , a new phase from the Lavrion ancient slags, Greece: occurrence and characterization	597
F. NEUHOLD, U. KOLITSCH, H.-J. BERNHARDT and C. L. LENGAUER: Arsenohopeite, a new zinc arsenate mineral from the Tsumeb mine, Namibia	603
M. ZEMA, A. M. CALLEGARI, S. C. TARANTINO, E. GASPARINI and P. GHIGNA: Thermal expansion of alunite up to dehydroxylation and collapse of the crystal structure	613
S. J. MILLS, J. SEJKORA, A. R. KAMPF, I. E. GREY, T. J. BASTOW, N. A. BALL, P. M. ADAMS, M. RAUDSEPP and M. A. COOPER: Krásnoite, the fluorophosphate analogue of perhamite, from the Huber open pit, Czech Republic and the Silver Coin mine, Nevada, USA	625
T. MIYAZOE, M. ENAMI, T. NISHIYAMA and Y. MORI: Retrograde strontium metasomatism in serpentinite mélange of the Kurosegawa Zone in central Kyushu, Japan	635
P. C. PIILONEN, A. M. McDONALD, G. POIRIER, R. ROWE and A. O. LARSEN: The mineralogy and crystal chemistry of alkaline pegmatites in the Larvik Plutonic Complex, Oslo rift valley,	

CONTENTS

Norway. Part 1. Magmatic and secondary zircon: implications for petrogenesis from trace-element geochemistry	649
I. V. PEKOV, M. E. ZELENSKI, N. V. ZUBKOVA, V. O. YAPASKURT, N. V. CHUKANOV, D. I. BELAKOVSKIY and D. YU. PUSHCHAROVSKY: Calciolangbeinite, $K_2Ca_2(SO_4)_3$, a new mineral from the Tolbachik volcano, Kamchatka, Russia	673
M. D. RUIZ-CRUZ and C. SANZ DE GALDEANO: Diamond and coesite in ultrahigh-pressure–ultrahigh-temperature granulites from Ceuta, Northern Rif, northwest Africa	683
E. V. GALUSKIN, J. KUSZ, T. ARMBRUSTER, R. BAILAU, I. O. GALUSKINA and B. TERNES: A reinvestigation of mayenite from the type locality, the Ettringer Bellerberg volcano near Mayen, Eifel district, Germany	707
<i>Letter</i>	
A. M. KASSI, A. K. KASI, A. TAWAB KHAN and A. SALAM KHAN: Comments on the eruption of basaltic magma at Tor Zavar, Balochistan, Pakistan on 27 January 2010, with a discussion of the geochemical and petrological constraints on its petrogenesis	717
N. V. CHUKANOV, R. SCHOLZ, S. M. AKSENOV, R. K. RASTSVETAEVA, I. V. PEKOV, D. I. BELAKOVSKIY, K. KRAMBROCK, R. M. PANIAGO, A. RIGHI, R. F. MARTINS, F. M. BELOTTI and V. BERMANEC: Metavivianite, $Fe^{2+}Fe^{3+}(PO_4)_2(OH)_2 \cdot 6H_2O$: new data and formula revision	725
A. GUASTONI, L. BINDI and F. NESTOLA: Debattistiite, $Ag_9Hg_{0.5}As_6S_{12}Te_2$, a new Te-bearing sulfosal from Lengenbach quarry, Binn valley, Switzerland: description and crystal structure	743
T. BALIĆ-ŽUNIĆ, A. GARAVELLI, D. MITOLO, P. ACQUAFREDDA and E. LEONARSEN: Jakobssonite, $CaAlF_5$, a new mineral from fumaroles at the Eldfell and Hekla volcanoes, Iceland	751
A. GUASTONI, F. NESTOLA, C. FERRARIS and G. PARODI: Xenotime-(Y) and Sn-rich thortveitite in miarolitic pegmatites from Baveno, Southern Alps, Italy	761
S. J. MILLS, A. R. KAMPF, A. M. McDONALD, G. FAVREAU and P.-J. CHIAPPERO: Forêtite, a new secondary arsenate mineral from the Cap Garonne mine, France	769
<i>Review</i>	
D. R. BROOKSHAW, R. A. D. PATRICK, J. R. LLOYD and D. J. VAUGHAN: Microbial effects on mineral–radionuclide interactions and radionuclide solid-phase capture processes	777
<i>CNMNC Newsletter 13</i>	
P. A. WILLIAMS, F. HATERT, M. PASERO and S. J. MILLS: New minerals and nomenclature modifications approved in 2012	807
Obituary	819

[No. 497, AUGUST 2012]

J. P. DAVIDSON and G. DIEGO GATTA: Mark Welch Special issue	823
F. CÂMARA, F. NESTOLA, L. BINDI, A. GUASTONI, F. ZORZI, L. PERUZZO and D. PEDRON: Tazzoliite: a new mineral with a pyrochlore-related structure from the Euganei hills, Padova, Italy	827
M. A. COOPER and F. C. HAWTHORNE: Refinement of the crystal structure of zoned philipsbornite–hidalgoite from the Tsumeb mine, Namibia, and hydrogen bonding in the $D^{2+}G_3^{3+}(T^{5+}O_4)(TO_3OH)(OH)_6$ alunite structures	839
A. R. KAMPF, S. J. MILLS, R. M. HOUSLEY, P. A. WILLIAMS and M. DINI: Alcaparrosaite, $K_3Ti^{4+}Fe^{3+}(SO_4)_4O(H_2O)_2$, a new hydrophobic Ti^{4+} sulfate from Alcaparrosa, Chile	851
E. SOKOLOVA: Further developments in the structure topology of the astrophyllite-group minerals	863
R. TURNER, O. I. SHIDRA, M. S. RUMSEY, S. V. KRIVOVICHEV, C. J. STANLEY and J. SPRATT: Hereroite and vladkrivovichevite: two novel lead oxychlorides from the Kombat mine, Namibia	883
P. LEVERETT, J. K. REYNOLDS, A. J. ROPER and P. A. WILLIAMS: Tripuhyite and schafarzikite: two of the ultimate sinks for antimony in the natural environment	891
F. BELLATRECCIA, G. DELLA VENTURA, G. D. GATTA, M. CESTELLI GUIDI and S. HARLEY: Carbon dioxide in pollucite, a feldspathoid with the ideal composition $(Cs,Na)_{16}Al_{16}Si_{32}O_{96} \cdot nH_2O$	903
W. A. CRICHTON, M. MERLINI, H. MÜLLER, J. CHANTEL and M. HANFLAND: The high-pressure monazite-to-scheelite transformation in $CaSeO_4$	913

CONTENTS

D. P. DOBSON, R. MCCORMACK, S. A. HUNT, M. W. AMMANN, D. WEIDNER, L. LI and L. WANG: The relative strength of perovskite and post-perovskite NaCoF ₃	925
G. DIEGO GATTA, P. LOTTI, V. KAHLENBERG and U. HAEFEKER: The low-temperature behaviour of cancrinite: an <i>in situ</i> single-crystal X-ray diffraction study	933
A. K. KLEPPE, M. D. WELCH, W. A. CRICHTON and A. P. JEPHCOAT: Phase transitions in hydroxide perovskites: a Raman spectroscopic study of stottite, FeGe(OH) ₆ , to 21 GPa	949
G. O. LEPORE, T. BOFFA BALLARAN, F. NESTOLA, L. BINDI, D. PASQUAL and P. BONAZZI: Compressibility of β-As ₄ S ₄ : an <i>in situ</i> high-pressure single-crystal X-ray study	963
S. J. MILLS and F. NESTOLA: Elasticity and high-pressure structure of arsenoflorencite-(La): insights into the high-pressure behaviour of the alunite supergroup	975
F. NESTOLA, D. PASQUAL, M. D. WELCH and R. OBERTI: The effects of composition upon the high-pressure behaviour of amphiboles: compression of gedrite to 7 GPa and a comparison with anthophyllite and proto-amphibole	987
S. A. T. REDFERN, S. E. SMITH and E. R. MADDRELL: High-temperature breakdown of the synthetic iodine analogue of vanadinite, Pb ₅ (VO ₄) ₃ I: an apatite-related compound for iodine radioisotope immobilization?	997
C. M. B. HENDERSON, F. R. RICHARDSON and J. M. CHARNOCK: The Highwood Mountains potassic igneous province, Montana: mineral fractionation trends and magmatic processes revisited	1005

[No. 498, OCTOBER 2012]

S. J. MILLS, A. G. CHRISTY, A. R. KAMPF, R. M. HOUSLEY, G. FAVREAU, J.-C. BOULLIARD and V. BOURGOIN: Zincalstibite-9R: the first nine-layer polytype with the layered double hydroxide structure-type	1053
M. NAGASHIMA and T. ARMBRUSTER: Palenzonaite, berzeliite, and manganberzeliite: (As ⁵⁺ , V ⁵⁺ , Si ⁴⁺)O ₄ tetrahedra in garnet structures	1063
L. MELLUSO, R. K. SRIVASTAVA, C. M. PETRONE, V. GUARINO and A. K. SINHA: Mineralogy and magmatic affinity of the Jasra intrusive complex, Shillong Plateau, India	1081
O. D. OSBORNE, A. PRING, R. S. POPELKA-FILCOFF, J. W. BENNETT, A. STOPIC, M. D. GLASCOCK and C. E. LENEHAN: Comparison of the relative comparator and k ₀ neutron activation analysis techniques for the determination of trace-element concentrations in pyrite	1101
M. A. COOPER, Y. A. ABDU, N. A. BALL, F. C. HAWTHORNE, M. E. BACK, K. T. TAIT, J. SCHLÜTER, T. MALCHEREK, D. POHL and G. GEBHARD: Ianbruceite, ideally [Zn ₂ (OH)(H ₂ O)(AsO ₄)](H ₂ O) ₂ , a new arsenate mineral from the Tsumeb mine, Otjikoto (Oshikoto) region, Namibia: description and crystal structure	1119
I. V. PEKOV, N. V. CHUKANOV, S. N. BRITVIN, Y. K. KABALOV, J. GÖTTLICHER, V. O. YAPASKURT, A. E. ZADOV, S. V. KRIVOVICHEV, W. SCHÜLLER and B. TERNES: The sulfite anion in ettringite-group minerals: a new mineral species hielscherite, Ca ₃ Si(OH) ₆ (SO ₄)(SO ₃)·11H ₂ O, and the thaumasite–hielscherite solid-solution series	1133
L. BINDI, F. NESTOLA, A. GUASTONI, L. PERUZZO, M. ECKER and R. CARAMPIN: Raberite, Tl ₅ Ag ₄ As ₆ SbS ₁₅ , a new Tl-bearing sulfosalt from Lengenbach quarry, Binn valley, Switzerland: description and crystal structure	1153
I. E. GREY, C. M. MACRAE, E. KECK and W. D. BIRCH: Aluminium-bearing strunzite derived from jahnsite at the Hagedorf-Süd pegmatite, Germany	1165
A. R. KAMPF, S. J. MILLS, M. S. RUMSEY, M. DINI, W. D. BIRCH, J. SPRATT, J. J. PLUTH, I. M. STEELE, R. A. JENKINS and W. W. PINCH: The heteropolymolybdate family: structural relations, nomenclature scheme and new species	1175
R. W. TURNER, O. I. SIDRA, S. V. KRIVOVICHEV, C. J. STANLEY and J. SPRATT: Rumseyite, [Pb ₂ OF]Cl, the first naturally occurring fluoroxychloride mineral with the parent crystal structure for layered lead oxychlorides	1209
S. J. MILLS, A. R. KAMPF, R. M. HOUSLEY, G. FAVREAU, M. PASERO, C. BIAGIONI, S. MERLINO, C. BERBAIN and P. ORLANDI: Omsite, (Ni,Cu) ₂ Fe ³⁺ (OH) ₆ [Sb(OH) ₆], a new member of the cualstibite group from Oms, France	1219

CNMNC Newsletter 14

CONTENTS

P. A. WILLIAMS, F. HATERT, M. PASERO and S. J. MILLS: New minerals and nomenclature modifications approved in 2012	1227
F. C. HAWTHORNE: Bond topology and structure-generating functions: graph-theoretic prediction of chemical composition and structure in polysomatic T–O–T (biopyrribole) and H–O–H structures	1235
D. KOSSOFF, K. A. HUDSON-EDWARDS, W. E. DUBBIN, M. ALFREDSSON and T. GERAKI: Cycling of As, P, Pb and Sb during weathering of mine tailings: implications for fluvial environments	1263

[No. 499, NOVEMBER 2012]

Goldschmidt Abstracts 2012 (available online only)

[No. 500, DECEMBER 2012]

K. A. HUDSON-EDWARDS, N. J. G. PEARCE and R. WARRENDER: Frontiers in Environmental Geoscience 2011 – Introduction	2641
P. E. REILLER: Modelling metal–humic substances–surface systems: reasons for success, failure and possible routes for peace of mind	2643
J. SÁNCHEZ-ESPAÑA, I. YUSTA and G. A. LÓPEZ: Schwertmannite to jarosite conversion in the water column of an acidic mine pit lake	2659
I. NANCUCHEO, S. HEDRICH and D. B. JOHNSON: New microbiological strategies that enable the selective recovery and recycling of metals from acid mine drainage and mine process waters	2683
A. A. BOGUSH, O. G. GALKOVA and N. V. ISHUK: Geochemical barriers to elemental migration in sulfide-rich tailings: three case studies from Western Siberia	2693
M. BOUBY, N. FINCK and H. GECKEIS: Flow field-flow fractionation (FIFFF) coupled to sensitive detection techniques: a way to examine radionuclide interactions with nanoparticles	2709
N. FINCK, M. BOUBY, K. DARDENNE and H. GECKEIS: Characterization of Eu(III) co-precipitated with and adsorbed on hectorite: from macroscopic crystallites to nanoparticles	2723
J. D. PASTERIS, C. H. YODER, M. P. STERNLIEB and S. LIU: Effect of carbonate incorporation on the hydroxyl content of hydroxylapatite	2741
V. N. YAKOVENCHUK, E. KECK, S. V. KRIVOVICHEV, Y. A. PAKHOMOVSKY, E. A. SELIVANOVA, J. A. MIKHAILOVA, A. P. CHERNYATIEVA and G. YU. IVANYUK: Whiteite-(CaMnMn), CaMnMn ₂ Al ₂ [PO ₄] ₄ (OH) ₂ ·8H ₂ O, a new mineral from the Hagendorf-Süd granitic pegmatite, Germany	2761
F. DEMARTIN, I. CAMPOSTRINI, C. CASTELLANO, C. M. GRAMACCIOLI and M. RUSSO: D'ansite-(Mn), Na ₂₁ Mn ²⁺ (SO ₄) ₁₀ Cl ₃ and d'ansite-(Fe), Na ₂₁ Fe ²⁺ (SO ₄) ₁₀ Cl ₃ , two new minerals from volcanic fumaroles	2773
R. THOMAS and P. DAVIDSON: Evidence of a water-rich silica gel state during the formation of a simple pegmatite	2785
A. R. KAMPF, J. MARTY, B. P. NASH, J. PLÁŠIL, A. V. KASATKIN and R. ŠKODA: Calciodelrioite, Ca(VO ₃) ₂ (H ₂ O) ₄ , the Ca analogue of delrioite, Sr(VO ₃) ₂ (H ₂ O) ₄	2803
M. A. COOPER and F. C. HAWTHORNE: The crystal structure of kraisslite, ⁴¹ Zn ₃ (Mn,Mg) ₂₅ (Fe ³⁺ ,Al)(As ³⁺ O ₃) ₂ [(Si,As ⁵⁺)O ₄] ₁₀ (OH) ₁₆ , from the Sterling Hill mine, Ogdensburg, Sussex County, New Jersey, USA	2819
J. PLÁŠIL, J. HAUSER, V. PETŘÍČEK, N. MEISSER, S. J. MILLS, R. ŠKODA, K. FEJFAROVÁ, J. ČEJKA, J. SEJKORA, J. HLOUŠEK, J.-M. JOHANNET, V. MACHOVIČ and L. LAPČÁK: Crystal structure and formula revision of deliensite, Fe[(UO ₂) ₂ (SO ₄) ₂ (OH) ₂](H ₂ O) ₇	2837
Obituary	2861
Referees	2863

[No. 501, DECEMBER 2012]

Special issue: Geological disposal of radioactive waste (available online only)

Archaeo-environmental characterization of the Arvernian gold mines of Auvergne (France)

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During the Iron Age, the Gaulish *Arverni* and *Lemovices* influence extended well beyond Auvergne (Central France), into the Mediterranean regions owing to extensive agricultural activities and silver mining. Recent discoveries showed that gold mining in the area of Haute-Combraille (Auvergne) may also have contributed to the wealth of these communities. Gold was possibly extracted as well during the first two centuries AD. at the onset of Roman occupation.

Our project (MINEDOR) aims to study from an interdisciplinary and diachronic point of view these ancient gold mines, traditionally attributed to the Gaulish period, discovered in large numbers at the fringes of the *Arverni* and *Lemovices* territories, in the area of Upper Combraille (Puy-de-Dôme). Our goals are 1) to accurately identify the mines through fieldwalking and aerial surveys, analysis of vertical aerial photographic coverage and localization by dual-frequency DGPS, 2) to assess their environmental impact using palaeoenvironmental (palynology, microfossils) and geochemical (heavy metals, trace elements, stable lead isotopes) analyses in wetlands, and 3) to date transient phases of exploitation.

Here we present high-resolution peat core analyses from the Haute-Combraille highlands (900-1000m) that allow to evidence gold mining operational phases since the Iron Age through vegetation cover changes and the release of lead (Pb) from mining activities. These new data highlight important features of the ancient economy of the Massif Central and the transient environmental impact of mining operation on watershed quality.

Advances in MC-TI-MS for precise and accurate Ca isotopic analysis

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Ca isotopes have proved to be powerful isotopic tracers in a number of disciplines within Geosciences, including Paleoceanography, Geochronology and Biogeochemistry, and Cosmochemistry, where minute anomalies relative to Earth are a key to deciphering the origin of Earth and the terrestrial planets. However, accurate and precise Ca isotope analysis is highly challenging, due to, both, the extreme range of relative Ca isotopic abundances - ⁴⁰Ca alone representing 97% of Ca isotopes - and the extreme mass dispersion of the Ca isotope array of 20%. These limiting features have prevented optimized multicollection (MC) analysis of all Ca isotopes, and introduced uncertainties due to ion beam instabilities and inferior counting statistics for the minor Ca isotopes. Precision and accuracy can be improved by optimizing sample loading and double spike techniques, but ultimately, there is a need for improved mass spectrometry performance in order to improve the state-of-the-art for Ca isotopic analysis.

The TRITON *Plus* offers new solutions to address these analytical challenges:

[1] An extended mass dispersion provides *simultaneous collection of all Ca isotopes*, without the requirement of applying a zoom to deflect the Ca ion beam. Peak-jumping mode is no longer required for Ca isotope analysis, thus saving acquisition time and limiting the potential detrimental effects of Ca ion-beam instabilities on precision and reproducibility.

[2] Different gain current amplifiers (10¹⁰, 10¹¹ and 10¹² Ohm) can be combined. The 10¹² Ohm amplifiers provide a factor of 2-3 improvement in the signal/noise ratio relative to a classical 10¹¹ Ohm amplifier, and can be associated to the cup(s) collecting the minor Ca isotope(s). Additionally, a 10¹⁰ Ohm amplifier can be connected to the cup collecting ⁴⁰Ca, and hence increase the dynamic range by a factor of 100. Amplifier switching to any cup is supported by the tried and tested relay matrix already equipping TRITON instruments. The combination of these current amplifiers ultimately contributes to enhancing Ca isotope in-run precision through improved ion counting statistics and by application of more precise instrumental mass fractionation correction as the normalizing ratio ⁴²Ca/⁴⁴Ca can be determined at 10 times higher beam intensities.

[3] The new TRITON *Plus* Ca package consists of 2 special cups: an extended cup attached on the high mass side of the focal plane that accommodates acquisition of the heaviest Ca isotope (⁴⁸Ca); and an oversized cup on the low mass side of the focal plane for the high intensity ⁴⁰Ca beam.