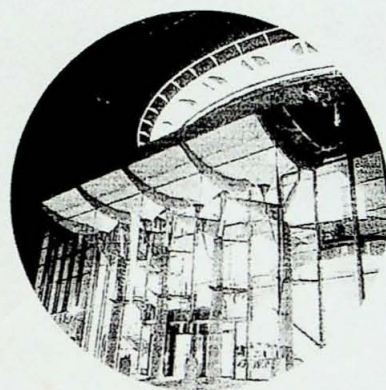
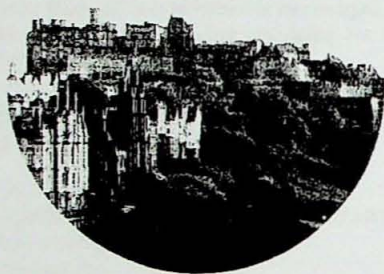


# 18th GENERAL MEETING OF THE INTERNATIONAL MINERALOGICAL ASSOCIATION

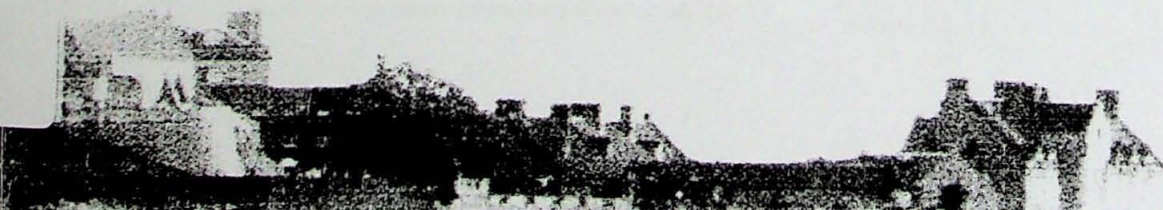
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## Session 22 Abstracts

## POSTERS for Session 22

**B22-1: Fluid inclusions in calcite and sources of ore-forming fluid in the Huize Ge-Ag-Pb-Zn deposit, Yunnan, China**Runsheng Han<sup>1,2</sup>, Congqiang Liu<sup>1</sup>, Zhilong Huang<sup>1</sup>, Yuan Li<sup>2</sup>, Deyun Ma<sup>1,2</sup> and Jin Chen<sup>3</sup><sup>1</sup>Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002, PRC<sup>2</sup>Kunming University of Science and Technology, Kunming 650093, PRC. hrs331@sohu.com; hanrunsheng331@X263.net<sup>3</sup>Huize Pb-Zn Mine, Yunnan 654211, PRC

The Huize super-large carbonate-hosted Ge-Ag-Pb-Zn deposit is a typical MVT-type deposit. Fluid inclusions in the major gangue mineral (calcite) are abundant and occur in concentrated groups along crystallographic planes. The inclusions are generally small (~1–10 µm), and are mainly of two types: pure-liquid inclusions and liquid-vapour inclusions.

Based on homogenization temperature and salinity measurements, and data on the hydrogen, oxygen and carbon isotopes of calcite from the Huize deposit,  $\delta D$  (–43.5 to –75‰),  $\delta^{18}O_{SMOW}$  (–17.09–18.56‰),  $\delta^{13}C_{PDB}$  (–1.2 to –3.27‰ (17 samples)) the nature of the ore-forming fluid can be discussed. The geochemical study indicates that the ore-forming fluid is characterized by the medium salinity (5–10.8 wt.% NaCl), moderate temperature (~168–245°C), and medium pressure (~410–661×10<sup>5</sup> Pa). It is considered that the fluid containing Pb and Zn belongs to the Na<sup>+</sup>-Cl-SO<sub>4</sub><sup>2-</sup> type. The ore-forming fluid may have come from magmatic water and circulating water from the deep basement and overlying cover. The sources of ore-forming fluid may also be related to metamorphism. The ore-bodies themselves may have resulted from ascending circulating ore-forming fluid at depth, which is enriched in Pb, Zn and etc.

**B22-2: Chlorite rich and opalescent quartz from São Geraldo do Araguaia, State of Pará, Brazil**T. A. Collyer<sup>1</sup> and B. Kotschoubey<sup>2</sup><sup>1</sup>Department of Industry, Commerce and Mining, Government of the State of Pará, Brazil.

mineracao@seicom.pa.gov.br

<sup>2</sup>Department of Geochemistry and Petrology, Center of Earth Sciences, Federal University of the State of Pará, Brazil. basile@ufpa.br

Opalescent quartz was recently discovered near São Geraldo do Araguaia, state of Pará. The deposit consists of sub-meridian and sub-vertical, roughly symmetric veins up to 2m thick, hosted by micaschists and quartzites of the Neoproterozoic Morro do Campo Formation, Estrondo Group, belonging to the Araguaia Fold Belt. The zones of these veins are composed of massive, milky to greyish quartz, coarse small black tourmaline, specular hematite and pyrite crystals, while the inner zone is essentially formed by prismatic, centimetric to decimetric hyaline quartz crystals displaying comb-like texture and containing, in places, reddish to yellowish, commonly needle-like rutile inclusions in part altered to anatase, variable amounts of dark green clinohlore flakes and, subordinately, specularite and pyrite crystals. Some of these quartz crystals exhibit an optical effect similar to the cat's-eye effect, due to the regular alternation of thin hyaline zones and zones rich in minute, euhedral, whitish leuchtenbergite flakes, resulting from epitaxial overgrowth. When the leuchtenbergite inclusions are particularly abundant and homogeneously distributed, they confer opalescence to the host quartz.

Fluids of the H<sub>2</sub>O-KCl-NaCl system, displaying salinity from 18.80 to more than 23.18 equiv. wt percent NaCl and Th from 293°C to 345°C were identified in the border zones. The fluids of the inner zone showed to be of the same system, revealing, however, much lower salinity and Th (from 4.34 to 5.26 equiv. wt percent NaCl and 136°C to 198°C, respectively). The composition of the clinohlore inclusions obtained by SEM-EDS analyses suggests that this mineral crystallized in a temperature range from 266°C to 315°C.

The decreasing salinity and Th of the fluids from the borders to the inner zone suggest that the veins underwent a complex evolution. It is believed that during the final, pressure release-related, distensive stage of the Brasiliano tectonic event, preexistent fractures were reactivated draining, initially, saline and high temperature fluids of magmatic and/or deep metamorphic origin, that were responsible for the formation of the massive vein borders. Such an hypothesis is sustained by the presence of discrete, late to post-tectonic granitoid bodies in the São Geraldo do Araguaia region. Later, as the contribution of shallower, probably meteoric waters increased, the fluid temperature and salinity progressively decreased, allowing the

formation of prismatic, hyaline quartz megacrystals containing clinohlore and rutile inclusions. At present, chlorite-rich and opalescent quartz is used as gemstone, ornamental stone and in mineral craftsmanship.

**B22-3: Calcite Crystal Growth At The Dalen-Kjørholt Limestone Mine, Southwest Oslo Region**

C.J. Hetherington and A.O. Harstad

Geologisk museum, Universitetets Naturhistoriske Museer og

Botanisk Hage, Universitetet i Oslo, Postboks 1172 Blindern, NO-

0318 Oslo, Norway.

callum.hetherington@nhm.uio.no

The Dalen-Kjørholt mine, on the Eidanger peninsula in the southwest Oslo Region, extracts limestone from the Ordovician Steinvik Formation. The Steinvik Formation is 41 metres thick and forms part of the Cambro-Silurian sedimentary sequence of the Oslo region. Here, the Cambro-Silurian rocks are bounded by Proterozoic basement in the west, and the late-Carboniferous larvikite intrusive complex in the east. All meta-sedimentary units strike NNW-SSE and have an easterly dip, which increases in magnitude towards the larvikite complex. The metasedimentary and basement rocks are cut by a series of east-west normal faults. The relationship between the faults and the larvikite cannot be observed.

The mine covers a area of 4km<sup>2</sup>. It is well known to crystal collectors and over 250 calcite morphologies have been reported. The calcite crystals are found in veins related to the normal faults or in large cavities that resemble natural caves. Sequences of mineral precipitation have been elucidated by detailed investigation of the veins and cavities, the minerals, and their inclusions.

In many natural caves calcite is found to be overgrown first by quartz + zeolite. This is followed by a second generation of calcite + quartz + zeolite. In fault related localities the mineral precipitation sequence is dominated by several generations of calcite, with a very late overgrowth of either pyrite or quartz.

Fluid inclusion studies indicate that the assemblage in the smaller fractures and veins grew from a CO<sub>2</sub>-rich fluid, possibly from a local source. The assemblage in the larger cavities appears to have precipitated from a more water-rich fluid. The stable isotope ratios of the cavity calcite are strongly depleted relative to the Steinvik Formation limestone. Thus it is proposed that these more water-rich fluids are from an external source.

There is no evidence that fluids escaped from the nearby larvikite intrusions and they are unlikely to be the source of the external fluid. However, the larvikites were probably important in mobilizing fluids in the Cambro-Silurian rocks during contact metamorphic-related devolatilization. It is proposed that the mobilised fluids moved through large faults and natural cave systems. Depressurisation of fluid in large cavities, such as caves, resulted in the mineral precipitation. The repetitive nature of the assemblages in the caves suggests that several pulses of fluids from a similar source were responsible for the observed mineral assemblages. This implies tectonic control of metamorphic fluid release.

**B22-4: Fluid Inclusions in Quartz from Veins and Metachert of the Au-Bearing Serra do Itaberaba Group, São Paulo, Brazil**G.M. Garda<sup>1</sup>, P. Beljavskis<sup>1</sup> and D. Silva<sup>2</sup><sup>1</sup>Instituto de Geociências da USP, Rua do Lago 562, 05508-900 - São Paulo, Brazil

giagarda@usp.br

<sup>2</sup>Instituto de Geociências da UNICAMP, CP 6152, 13083-970 - Campinas - São Paulo, Brazil

Fluid inclusions in quartz from veins and metachert of the Tapera Grande and Quartzito areas (Serra do Itaberaba Group - São Paulo, Brazil) were classified into four groups according to phase ratios at room temperature: i) monophasic aqueous; ii) two-phase (H<sub>2</sub>O-rich, CO<sub>2</sub>-poor); iii) two-phase/three-phase (H<sub>2</sub>O-CO<sub>2</sub>-rich, CH<sub>4</sub>-poor/absent, variable V/L ratio), and iv) multiphasic (with possible accidental crystalline phase).

The microthermometric properties for inclusions in quartz from barren veins (average Tm<sub>CO2</sub> = -57°C and Th<sub>CO2</sub> = 21°C) and mineralized (average Tm<sub>CO2</sub> = -56.8°C and Th<sub>CO2</sub> = 27°C) veins and metachert of Tapera Grande show slight variations, but vary more markedly for metachert (average Tm<sub>CO2</sub> = -58.5°C to



-57°C and  $\text{Th}_{\text{CO}_2} = 20^\circ\text{C}$  to  $25^\circ\text{C}$ ) and quartz veins of Quartzito (average  $\text{Tm}_{\text{CO}_2} = -57^\circ\text{C}$  to  $-56.5^\circ\text{C}$  and  $\text{Th}_{\text{CO}_2} = 16^\circ\text{C}$  to  $26^\circ\text{C}$ ). Salinity values obtained from clathrate melting temperatures are within the range 0 to 5 wt.% NaCl equiv. for inclusions in metachert quartz ( $\text{Tm}_{\text{clath}} = 7^\circ\text{C}$  to  $10^\circ\text{C}$ ), whereas those for vein quartz show a wider variation from 4 and 12 wt.% NaCl equiv ( $\text{Tm}_{\text{clath}} = 3^\circ\text{C}$  to  $8^\circ\text{C}$ ). Raman spectroscopy revealed a predominance of  $\text{CO}_2$  (> 80%), subordinate amounts of  $\text{CH}_4$  and rare  $\text{N}_2\text{O}$  in the carbonic phase for inclusions in metachert quartz. The overall densities are above 0.7 g/cm<sup>3</sup>. Total homogenization for inclusions in metachert quartz occurs at temperatures around 250-275°C. In most cases, decrepitation is observed at 238°C and 286°C. Smaller inclusions homogenize at 270°C and 320°C.

Despite the fact that the fluid inclusion evidence indicates metamorphic-hydrothermal sources for the mineralizing fluids (Beljanskis *et al.*, 2000), the observed differences may explain the presence of Au in metachert and associated rocks in Tapera Grande (e.g. graphite schists, tourmalinites) and Quartzito (e.g. iron formation) and more abundant copper sulphides in the (barren?) quartz veins of Quartzito. As pointed out by Garda *et al.* (2000), disseminated gold is associated with syn-sedimentary sulphides in Tapera Grande, whereas in Quartzito hydrothermal fluids associated with shearing caused epigenetic sulphide (and  $\pm$  Au) deposition.

## B22-5: Submicron polyphase inclusions in zoned garnets from the Picuris range, New Mexico: Implications for disequilibrium Ca and trace element zonation

Adrian J. Brearley<sup>1</sup> and William D. Carlson<sup>2</sup>

<sup>1</sup>Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, USA  
brearley@unm.edu

<sup>2</sup>Department of Geological Sciences, University of Texas at Austin, Austin, TX 78712 USA

We have used TEM techniques to study zoned almandine-rich garnets from the Picuris range of north central New Mexico. The garnets occur in the proterozoic Rinconada Formation which reached peak metamorphic conditions just above the aluminosilicate triple point. During growth of these garnets, Mn, Mg and Fe achieved chemical equilibrium during garnet growth, but Ca did not. This has resulted in the development of distinct Ca-rich spikes in zoning profiles that has been attributed to thermally accelerated diffusion-controlled garnet growth. The spikes in Ca concentrations are also correlated with elevated concentrations of trace elements such as Y, Yb, P and Ti. We are studying these garnets to establish if the observed behaviour of minor and trace elements can be explained by the presence of defects or sub-micron inclusions. TEM shows that the zone of Ca-enrichment is characterized by the presence of polyphase inclusions that range in size from 0.2-0.8 microns. The inclusions have faceted outlines that correspond to high symmetry crystallographic planes of the garnet. Preliminary data shows that all the inclusions studied consist of an iron-oxide phase, with a fibrous morphology, probably hematite, that is closely intergrown with a phyllosilicate phase with a composition consistent with chlorite ( $\text{Mg}/(\text{Mg}+\text{Fe}) = 0.47$ ). The chlorite often occurs in a disordered intergrowth with a second phyllosilicate phase with a basal spacing of 1 nm. Additional phases in the inclusions are carbonates (calcite and a Ca-Fe-Mn carbonate solid solution), rutile and Ti-bearing andraditic garnet. All these phases have grain sizes of <100 nm. The presence of hydrous phases within garnet could be the result of retrograde alteration following peak metamorphism. However, zones of retrograde alteration are present locally within the garnet, but the style and phase assemblage is quite different from that observed in the inclusions. Our working hypothesis to explain these observations is that the polyphase inclusion assemblage represents metastable phases that were included into the garnet during episodes of rapid prograde growth. We are exploring the possibility that these phases are the result of metamorphic reactions during the prograde reaction path that were limited by the isolation of the phase assemblage as inclusions in the garnet. These observations indicate that the elevated Ca and trace element concentrations is related to the presence of submicron inclusions.

## B22-6: Fluid inclusions in giant pegmatitic microcline crystals, Alto da Cabeça Parelhas, Rio Grande do Norte, Brazil

Vladimir Bermanec<sup>1</sup>, Ladislav Palinkas<sup>1</sup>, Sabina Strmic<sup>1</sup>, Vladimir Zebec<sup>2</sup>, Reinhard Wegner<sup>3</sup> and Walter Franz<sup>4</sup>

<sup>1</sup>University of Zagreb, Faculty of Science, Department of Geology, Institute of Mineralogy and Petrography, Horvátovac bb, HR-10000 Zagreb, Croatia [lpalinkas@public.srce.hr](mailto:lpalinkas@public.srce.hr)

<sup>2</sup>Natural history museum, Demetrova 1, HR-10001 Zagreb, Croatia

<sup>3</sup>Department of Geology, Federal University of Paraíba, Centro Campina Grande 58101-001, Brasil

<sup>4</sup>Institute for mineralogy, Karl Franz University of Graz, Universitätsplatz 2, Graz, Austria

The Boqueirão pegmatite body of Alto da Cabeça, Parelhas, Rio Grande do Norte, Brazil, contains giant microcline crystals which are classified as pure potassium feldspars. Their unit cell parameters are:  $a=8.584(3)\text{\AA}$ ,  $b=12.964(4)\text{\AA}$ ,  $c=7.215(3)\text{\AA}$ ,  $\alpha=90.62(4)^\circ$ ,  $\beta=115.97(4)^\circ$ ,  $\gamma=87.76(4)^\circ$ ,  $V=721.3(4)\text{\AA}^3$ . Most probably they crystallized as orthoclase and subsequently ordered their crystal structure during the history of pegmatite formation. Fluid inclusion (FI) studies of microcline, including laser Raman spectroscopy, revealed three different inclusion types: 1. One phase FIs, lacking any phase transition below 400°C. Raman spectroscopy suggests the presence of quenched melt inclusions; 2. Aqueous FIs,  $\text{Te} = -31^\circ\text{C}$  ( $-25.2$  to  $-32.7^\circ\text{C}$ ),  $\text{Tm Ice} = -5^\circ\text{C}$  ( $-1.8$  to  $-6.2^\circ\text{C}$ ),  $\text{Th V/L} = +190^\circ\text{C}$  ( $+170$  to  $+220^\circ\text{C}$ ); 3. Aqueous-carbonic FIs,  $\text{Tm CO}_2 = -65^\circ\text{C}$  ( $-60.5$  to  $-67.8^\circ\text{C}$ ), laser Raman spectroscopy determined 0.1 to 2.0 mole%  $\text{N}_2$ ,  $\text{Th CO}_2$  L/V and V/L =  $+29^\circ\text{C}$ , critical phenomena were not observed,  $\text{Tm clath} = +9.0^\circ\text{C}$  ( $+7.5$  to  $+9.5^\circ\text{C}$ ),  $\text{Th for V/L} = 200^\circ\text{C}$  ( $+165$  to  $+230^\circ\text{C}$ ). FIs in quartz differ only in  $\text{Th CO}_2 = +199^\circ\text{C}$ .

The crystallization path is approximated by using the intersection of isochores of coexisting aqueous and aqueous-carbonic FIs (Bowers and Helgeson, 1983; Potter and Brown, 1977). The presence of spodumene and quenched glass inclusions implies a melt pressure above 1500 bars and a gradual transition of silicic melt to hydrothermal solutions. Crystallization of tourmaline (schorl and elbaite), and consequent consumption of boron, produced acidic, aqueous fluids which caused ubiquitous kaolinitization and enhanced crystallization of microcline, quartz and other aluminosilicate phases introducing almost quenching effect on the borosilicate melt, which separated into silicic melt and aqueous fluids.

## B22-7: Raman Spectroscopy as a Tool for the identification of Hydrated and OH-Bearing Fe-bearing Daughter Minerals in Fluid Inclusions

P. Koděra<sup>1</sup>, A.H. Rankin<sup>2</sup> and P. Murphy<sup>2</sup>

<sup>1</sup>Geological Survey of the Slovak Republic, Mlynská dolina 1, Bratislava, 817 04, Slovakia  
[kodera@gsssr.sk](mailto:kodera@gsssr.sk)

<sup>2</sup>School of Earth Sciences and Geography, Kingston University, Kingston-upon-Thames, Surrey, KT1 2EE, UK

Hydrothermal, high temperature fluids related to acid to intermediate intrusives are often hypersaline (up to 80 wt% total dissolved salts) and often appear to be particularly rich in iron (up to 45 wt%  $\text{FeCl}_2$ ). Indications of high Fe contents are the occurrence of Fe-bearing minerals in associated fluid inclusions, but these are only rarely positively identified. Reliable identification of these daughters provides an important insight into Fe-contents, total salinity and redox state of the trapped fluid. Laser Raman Microspectroscopy is useful and powerful technique for the in situ identification of daughter minerals in fluid inclusions. Unfortunately, apart from a few common Fe-minerals, published reference spectra for water soluble Fe-salts, even in the simple system Fe-O-H-Cl, are sparse.

In this study full Raman spectra of hydrated  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  chlorides, erythrosiderite ( $\text{K}_2\text{Fe}^{2+}\text{Cl}_3\cdot\text{H}_2\text{O}$ ) and ferropyrrosmalite [ $(\text{Fe},\text{Mn})_2\text{Si}_2\text{O}_7(\text{OH},\text{Cl})_2$ ] were determined at  $+20$  and  $-180^\circ\text{C}$ , including the crucial, rarely recorded part of spectra at high wavenumbers, where the water-bending and stretching bands and molecular OH bands occur. In this part of spectra  $\text{FeCl}_2\cdot 4\text{H}_2\text{O}$  has major peaks at 3415, 3377, 3431, 1635, 1658cm<sup>-1</sup> (or 3428, 3392, 1621cm<sup>-1</sup> if heated above  $-50^\circ\text{C}$ ),  $\text{FeCl}_2\cdot 6\text{H}_2\text{O}$  at 3534, 3421, 3271cm<sup>-1</sup>, erythrosiderite at 3381, 3337, 1588cm<sup>-1</sup> and ferropyrrosmalite at 3551, 3591, 3627cm<sup>-1</sup> (all data for spectra recorded at  $-180^\circ\text{C}$ ).

These spectra, together with other published reference spectra, were used to identify the Fe-daughters present in inclusions in samples from four districts, each related to different types of hydrothermal ore: the Hodruša granodiorite related to Fe-skarn (Slovakia), the Dartmoor Granite related Sn-W-Fe veins (UK), the Mole Granite related to W-Mo-Sn in silicite (Australia) and the Chorloque Sn-porphry (Bolivia). Most semiquantitative SEM analysis suggest that many Fe daughters contain K and sometimes Mn in addition to Cl.