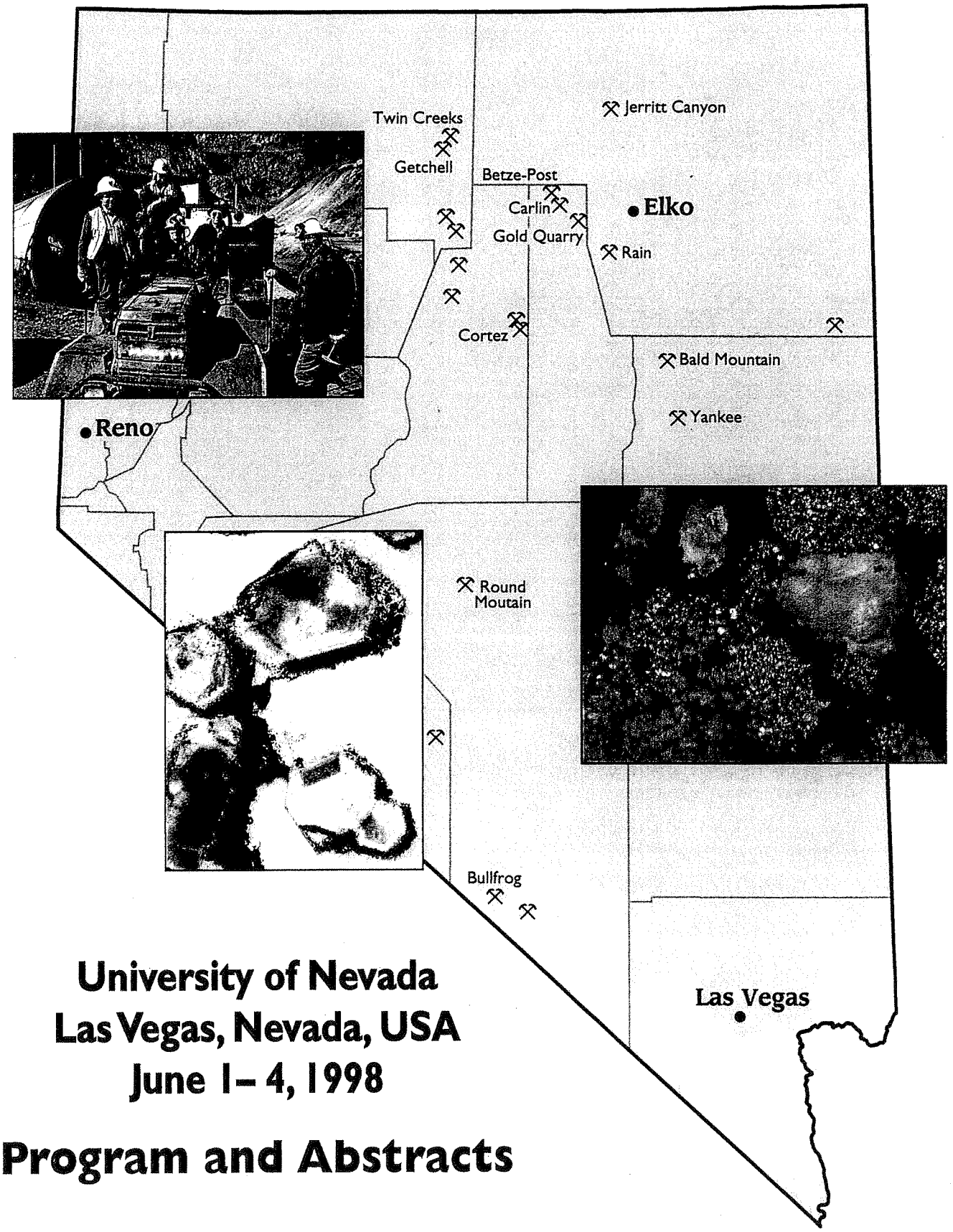
PACROFI VII



University of Nevada
Las Vegas, Nevada, USA
June 1– 4, 1998

Program and Abstracts

PACROFI VII

Pan–American Conference on Research on Fluid Inclusions

University of Nevada, Las Vegas
Department of Geoscience
Division of Continuing Education

Las Vegas, Nevada, USA
June 1–4, 1998

Program and Abstracts

Edited by
David A. Vanko and Jean S. Cline

NBMG Open-File Report 98-4
Nevada Bureau of Mines and Geology
Mail Stop 178, University of Nevada, Reno
Reno, NV 89557-0088

Cover photos:

Heidi Mertig (driver, Newmont Gold) leads a tour of the Carlin East underground mine for (left to right) Rich Kyle, The University of Texas at Austin, and Nevada Bureau of Mines and Geology geologists Steve Castor, Larry Garside, Chris Henry, and Jon Price (photographer).

White crystals: Fine, euhedral, ore-stage quartz crystals from the Getchell Carlin-type gold deposit, northern Nevada, with growth zones delineated by primary fluid inclusions. Quartz contains gold-bearing arsenic-rich pyrite and is rimmed by pyrite framboids and realgar. Vertical field of view is 400 micrometers. *Photo by J.S. Cline.*

Brassy and orange crystals: Intergrowth of hydrothermal pyrite framboids and realgar that rims euhedral, ore-stage quartz crystals from the Getchell, Carlin-type gold deposit, northern Nevada. Horizontal field of view is 80 micrometers. *Photo by J.S. Cline.*

Preface

Welcome to the seventh biennial gathering of the Pan American Conference on Research on Fluid Inclusions (PACROFI VII). PACROFI conferences provide a premier opportunity for an international group of researchers to gather and discuss the applications of fluid inclusion research to a diverse variety of geological problems. The international flavor of PACROFI continues this year with presentations by participants from seventeen countries including Argentina, Austria, Australia, Brazil, Canada, China, Czech Republic, England, France, Germany, Hungary, Mexico, Poland, Russia, Switzerland, United States, and Uzbekistan.

PACROFI VII follows six successful PACROFI meetings previously held in the United States, Canada, and Mexico. Presentations at this meeting will include 48 oral and 21 poster presentations. We wish to thank and acknowledge Dr. Edwin Roedder, United States Geological Survey, retired, and Dr. Robert Pottorf, Exxon Production Research Company, for their keynote presentations at this meeting. The abstract volume this year is being published by the Nevada Bureau of Mines and Geology as an open file report. We would like to thank Jon Price, Nevada State Geologist, and Susan Tingley, Kris Pizarro, and Jack Hursh of the Nevada Bureau of Mines and Geology for their assistance with the preparation of this volume.

Special thanks are due to the **National Science Foundation, Barrick Goldstrike Mines, Inc., Linkam Scientific Instruments, LTD.**, and **Homestake Mining Company** for financial support for this meeting. This funding has been used principally to offset travel, field trip, and meeting registration fees for students and young professionals, to facilitate their attendance at this meeting. We would also like to thank **Czarnowski Exhibit Service Specialists** for partial donation of the poster displays. In addition, we wish to thank Michelle Baker, Continuing Education at UNLV for logistical assistance, UNLV students Tracy Cail, Deborah Potts, Joel Rotert, Michiko Shigehiro, Kelli Weaver, and Dave Willard for assistance in running field trips, projectors, and assistance with social functions, and Robert Bodnar for assistance with planning.

We wish you an enjoyable visit while here in Las Vegas and trust that PACROFI VII will provide you with opportunities to confer with old friends, to meet new colleagues, and to initiate exciting new collaborative projects.

Jean S. Cline and Dave A. Vanko

Program - PACROFI VII

University of Nevada, Las Vegas

Tuesday, June 2
The Marjorie Barrick Museum Auditorium

(J. Dubessy and R. Bodnar, co-chairs)

8:30 **Welcoming remarks** - Jean Cline

8:45 Keynote address - *Ascending or Descending Water Flow Through Yucca Mountain Tuffs? - Fluid Inclusion Evidence.* Roedder, E., and Whelan, J.F.

9:20 *Traces of Epigenetic Hydrothermal Activity in the Yucca Mountain Volcanic Tuffs: Fluid Inclusion and Gas Chemistry Evidence.* Dublyansky, Y.

Analytical Methods

9:40 *Analysis of Methane at Low Concentration in Fluid Inclusions with Raman Spectroscopy.* Dubessy, J., Pironon, J., Lamb, W., McShane, C., Popp, B., and Thiéry, R.

10:00 *Coffee*

10:20 *Quantitative Analysis of Synthetic Fluid Inclusions in the H_2O-CH_4 System Using Raman Spectroscopy.* Leng, J., Sharma, A., Bodnar, R.J., Pottorf, R.J., and Vityk, M.O.

10:40 *Individual Fluid Inclusion Microanalysis Combining Proton-Induced and Photon-Induced X-Ray Emission (PIXE and SXRF).* Ménez, B., Philippot, P., Vanko, D.A., Mosbah, M., Chevalier, P., Drakopoulos, M., Populus, P., and Snigirev, A.

11:00 *Improvements for the Analysis of Individual Fluid Inclusions, Minerals and Glasses.* Fabre, C., Boiron, M., Dubessy, J., and Moissette, A.

11:20 *Mapping Trace-Metal (Cu, Zn, As) Distribution in Individual Fluid Inclusions Using a 3rd Generation Synchrotron Light Source (ESRF, France).* Philippot, P., Ménez, B., Drakopoulos, M., and Snigirev, A.

11:40 *Lunch*

(P. Brown and S. Hagemann, co-chairs)

Gold - I

1:20 *Multi-Phase Vein System at the Bronzewing Gold Deposit, Western Australia: Evidence for Homogeneous T-X Conditions During Ductile Shear Zone Development and Formation of the Vein System.* Dugdale, A.L., and Hagemann, S.G.

1:40 *Fluid Inclusion Analysis of a Shear Zone Hosted Lode Gold Deposit, Paddington, Western Australia.* Lee, T.J., and Brown, P.E.

2:00 *A Fluid Inclusion Study of the Fosterville Mine, Australia: A Turbidite-Hosted Gold Field.* Mernagh, T.P.

2:20 *Hydrothermal Fluids Associated with Intrusion-Related Au-Deposits with Lithophile Affinities: Examples From the Tombstone Plutonic Suite, Yukon.* Baker, T., Lang, J.R., and Mortensen, J.K.

2:40 *Fluid Inclusions and Quartz Textures in the Auriferous Veins of La Higuerita Mine, La Laguna Area, Córdoba, Argentina.* González, M.M., and Mas, G.R.

3:00 *Coffee*

3:20 Poster Presentations (21 Posters)

Gold - II

4:00 *The Bohemian Quartz Lode and Adjacent Vein Mineralization in the Bohemian Massif: An Example of Fluid Circulation in a Shear Zone.* Dobes, P., Zak, K., Leach, D., and Viets, J.

4:20 *The Evolution of Pressure, Temperature and Composition of Hydrothermal Fluids in a Regional Shear Zone During Retrograde Metamorphism, Regional Uplift, and Cooling: The Kasperske Hory Gold Deposit Case Study (Bohemian Massif, Czech Republic).* Zak, K., Durisova, J., Strnad, L., Golias, V., Leach, D., Snee, L.W., Viets, J., and Stein, H.J.

4:40 *Fluid Regime in Lode-Gold Deposits of the Proterozoic Seridó Belt, Borborema Province, NE Brazil.* Silva, W.L., Xavier, R.P., and Legrand, J.M.

5:00 Hosted Poster Session, The Marjorie Barrick Museum Foyer

Wednesday, June 3
The Marjorie Barrick Museum Auditorium

(R. Bakker and M. Vityk, co-chairs)

8:30 Keynote address: *Applications of Fluid Inclusion Technology to Hydrocarbon Systems.* Pottorf, R.J., and Vityk, M.O.

Petroleum

9:00 *Fluid and Thermal History of an Exhumed Petroleum Reservoir.* Brennan, S.T., and Goldstein, R.H.

9:20 *Major Fault Zones in the Cantabrian Zone (NW Spain): Possible Migration Paths for Petroleum.* Bakker, R.J., and Grimmer, J.

Chemical Systems and Synthetic Fluid Inclusions

9:40 *Theoretical Prediction of Phase Separation, PVT Properties, Enthalpy and Fugacity of Supercritical Fluids H_2O-CO_2-CH_4-N_2 up to 2000 K and 100 Kbar.* Duan, Z., Moller, N., and Weare, J.

10:00 *Coffee*

10:20 *Reequilibration of Synthetic CO_2-H_2O Fluid Inclusions in Quartz.* Bakker, R.J., and Diamond, L.W.

10:40 *Is the Assumption of Isochoric Fluid Inclusion Behavior Valid? A Raman Spectroscopic Study of P-T Paths of H_2O Fluid Inclusions.* Sharma, A., Leng, J., and Bodnar, R.J.

11:00 *Plastic Flow Associated with Reequilibration of Fluid Inclusions in Quartz.* Vityk, M.O., Bodnar, R.J., and Doukhan, J.

11:20 *Group Photograph — in front of Moger Student Union*

11:40 *Lunch*

(V. Lüders and K. Benison, co-chairs)

Evaporites

1:20 *ESEM X-Ray EDS: A New Technique for Major Element Chemical Analysis of Frozen Fluid Inclusions using an Environmental Scanning Electron Microscope with Attached Energy Dispersive System.* Timofeeff, M.N., Lowenstein, T.K., and Blackburn, W.H.

1:40 *Environmental SEM (ESEM) X-Ray EDS Chemical Analysis of Frozen Fluid Inclusions: Preliminary Results from Aqueous Standards, Fluid Inclusions in Laboratory-Grown Halite Crystals, and Phanerozoic Halites.* Timofeeff, M.N., Lowenstein, T.K., Blackburn, W.H., and Hardie, L.A.

2:00 *Investigations on Fluid Inclusions from Late Permian (Zechstein) Evaporites in Northern Germany.* Siemann, M.G., Klingenberg, I., and Prohl, H.

2:20 *Fluid Inclusions in Halite Indicate Extremely Acid Permian Lakes and Groundwaters.* Benison, K.C., Goldstein, R.H., Wopenka, B., Burruss, R.C., and Pasteris, J.D.

2:40 *Coffee*

Ore Deposits - I

3:00 *Cambrian VHMS Rosebery Deposit, Western Tasmania: Constraints from Metal Zonation and Fluid Inclusion Studies.* Khin Zaw, Huston, D.L., and Large, R.R.

3:20 *Formation of Massive Sulfide Ores and Barite in the Central Okinawa Trough, Japan: Evidence from Studies of Fluid Inclusions and Stable Isotopes.* Lüders, V., Pracejus, B., and Halbach, P.

3:40 *The Magmatic-Hydrothermal Evolution of a Tin Granite: The Mole Granite, Australia.* Audétat, A., Günther, D., and Heinrich C.A.

4:00 *Fluid Inclusions of the La Descubridora Tin Deposit: Evidence of Fluid Evolution.* Fogliata, A.S., González, M.M., and Mas, G.

4:20 *Fluid Inclusion Evidence for the Involvement of Basinal Brines and Granitic Fluids in the Development of Composite Cornish Sn-Lodes, SW England.* Rankin, A.H., Christoula, M., and Halls, C.

Thursday, June 4
The Marjorie Barrick Museum Auditorium

(A. Campbell and P. Nabelek, co-chairs)

Magmatic Systems

8:40 *Polycyclic Aromatic Hydrocarbons (PAH) in Diamonds and Other Minerals from the Kimberlite Pipes of Mir and Udachnaya-Vostochnaya.* Gassymova, F.I., and Melnikov, F.P.

9:00 *Preliminary Fluid Inclusion Results from the "El Muerto" Pegmatite, Oaxaca, Mexico.* Morales-Alvarado, M., and Prol-Ledesma, R.M.

9:20 *Fluid Inclusion Microthermometry in Be-Ta-(Li-Sn)-Bearing Pegmatites from the Borborema Province, Northeast Brazil.* Beurlen, H., da Silva, M.R.R., and de Castro, C.

9:40 *Melt Inclusion Investigation of the Volatile Behaviour of Fractionating Alkaline Magma, Mount Erebus, Ross Island, Antarctica.* Eschenbacher, A.J., Kyle, P.R., Lowenstern, J.B., and Dunbar, N.W.

10:00 *Coffee*

10:20 *The Origin of the Shoshonite-Latite Rock Series of Uksichan Volcano (Kamchatka, Russia), from Data on Melt Inclusions.* Prokofyev, V.Yu., Perepelov, A.B., and Belozerova, O.Yu.

10:40 *Inclusions in the Harney Peak Granite and its Associated Pegmatites (Black Hills, South Dakota): Implications on Geochemical Evolution of Magmatic Fluids in a Leucogranitic System.* Sirbescu, M., and Nabelek, P.

11:00 *A Model for the Temporal and Spatial Evolution of Magmatic Fluid Inclusions in Porphyry Copper Deposits.* Bodnar, R.J.

11:20 *Solid Inclusions of Halite in Quartz: Evidence for the Halite Trend.* Campbell, A.R., Wilson, S.A., and Dunbar, N.W.

11:40 *Lunch*

(J. Wilkinson and M. Cathelineau, co-chairs)

Ore Deposits - II

1:00 *Mantle Input into the Mineralizing Fluids of the Colorado Mineral Belt: The Noble Gas Story.* Thrower, C.D., Burnard, P.G., Turner, G., and Pattrick, R.A.D.

1:20 *Fracture-Controlled Flow of Mineralizing Fluids in Basement Rocks Beneath Carbonate-Hosted Base Metal Deposits, Ireland.* Wilkinson, J.J., and Everett, C.E.

1:40 *Fluid Inclusion and Stable Isotope Analyses Applied to Mississippi Valley-Type (Pb-Zn) Mineralization on Bathurst Island, N.W.T., Canada.* Rose, S.R.A., and Spencer, R.J.

2:00 *Geochemistry and Daughter Mineralogy of Late-Stage Carbonatitic Fluids: Implications for REE, Ba, Sr, U, and Base Metal Mineralization Processes Associated with Carbonatites.* Buehn, B., and Rankin, A.H.

2:20 *A Fluid Inclusion Study of Geodes from Rio Grande Do Sul, Brazil: Implications for the Origin of Quartz Geodes.* Lueth, V.W., and Goodell, P.C.

2:40 *Coffee*

Water-Rock Interaction

3:00 *Numerical Modeling of Water-Rock Interaction Using Reconstructed Fluid Composition: A Multi-Characterization of Alpine Fissure Fluids.* Cathelineau, M., Guerci, A., Banks, D., Boiron, M., and Ayt Ougougdal, M.

3:20 *Studies on the Filling of Pore Space in the Rotliegendes Sedimentary Rocks, SW Poland: Fluid Inclusions, Luminescence, Isotopes.* Jarmolowicz-Szulc, K.

3:40 *Density Differences in Fluid Inclusions from Mono- and Polymetamorphic Rocks in the Austroalpine Basement.* Kaindl, R., Abart, R., Hoinkes, G., and Knoll, P.

4:00 *Tracing Fluid Sources in an Active Hydrothermal System: A Case Study of the Geysers, California.* Moore, J.N., Norman, D.I., and Kennedy, B.M.

4:20 Business Meeting

5:00 Buses Leave for Lake Mead Cruise and Banquet

Poster Presentations

Genesis Conditions of the Berezovsk Gold Deposit, Middle Urals: Evidence from Fluid Inclusion and Isotopic Data. Baksheev, I., Prokofiev, V., and Ustinov, V.

Unusual Low Temperature Phase Behavior in the System H_2O-NaCl-$FeCl_2$. Baldassaro, P.M., and Bodnar, R.J.

3D Geometry Reconstruction and P-V-T-X Conditions of Microfissural Ore Fluid Migration in Crystalline Rocks: The Example of the Mokrsko Au-Bearing Granodiorite (Bohemian Massif). Boiron, M., Barakat, A., Cathelineau, M., Banks, D., Durisova, J., and Moravek, P.

Fluid Inclusions as a Monitor of Progressive Grain-Scale Deformation During Cooling of the Papoose Flat Pluton, Eastern California. Brauer, N.A., Bodnar, R.J., and Law, R.D.

Chemistry of Brines Migrating at the Basement-Sedimentary Cover Contact: The Example Of Soultz (Rhine Graben). Cathelineau, M., Banks, D., Boiron, M., Ayt Ougougdal, M., and Yardley, B.

The Gas Composition and Temperature of Fluids Related to Diamond Bearing Carbonatites, Western Uzbekistan. Divaev, F.K., Polickovsky, V.S., Ivanova, N.A., and Yudalevich, Z.A.

Comparison of LA-ICP-MS and Ion Chromatography Methods in the Analysis of Single Fluid Inclusions in Evaporites. Ellendorff, B., Schmidt, K., and Siemann, M.G.

Fluid Inclusion and Stable Isotope Geochemistry of a Cambrian to Ordovician Carbonate-Hosted Zinc Deposit, Southeastern Yukon, Canada. Heimbach, J.M., and Spencer, R.J.

Behavior of Synthetic Fluid Inclusions in the System H_2O-NaCl-CO_2-Ag. Krüger, Y., and Diamond, L.W.

Fluid Inclusions in Quartz and the Inference to Mineralization at Depth, Yinshan Polymetallic Deposit, Jiangxi Province, P.R. China. Liu Wei.

Fluid Inclusions in Quartz, Shibangou Gold Ore Deposit, Xixia, Henan, P.R. China. Liu Wei and Dehui Zhang.

The Mineralogic and Fluid Inclusion Record of the Transition from Liquid to Vapor-Dominated Conditions at the Geysers, California. Moore, J.N., Adams, M.C., and Anderson, A.J.

Volumetric Reconstruction of an Oil Inclusion Using Confocal Scanning Laser Spectroscopy. Pironon, J., Canals, M., Dubessy, J., Walgenwitz, F., Laplace-Builhe, C.

The Composition of Gases in Fluid Inclusions of Late Permian (Zechstein) Evaporites In Northern Germany. Prohl, H., and Siemann, M.G.

Fluid Regime and Conditions of Origin of the Sukhoi Log (Russia) Gold-Platinum Deposit. Prokofyev, V.Yu., Distler, V.V., Spiridonov, A.M., Grebenschikova, V.I., Yudovskaya, M.A., Matel, N.L., Mitrofanov, G.L., and Nemerov, V.K.

The System H_2O-NaCl-CO_2 at Elevated Temperatures, Pressures, and Salinities: Solvi, Lines of Equal Homogenization Temperature, and Critical Points. Schmidt, C., and Bodnar, R.J.

Mineral Paragenesis and Pressure and Temperature Constraints During Gold Mineralization at the Turquoise Ridge Carlin-Type Gold Deposit, Nevada. Shigehiro, M., and Cline, J.S.

Formation of Magnetite-Scheelite Skarn Mineralization at Kara, Northwestern Tasmania: Constraints from Mineral Paragenesis, Fluid Inclusion and Oxygen Isotope Studies. Singoyi, B., and Khin Zaw.

Fe-Rich Hypersaline Aqueous and CO_2 Inclusions Associated with Retrograde Metamorphism of the Chlorite-Muscovite-Quartz Schist from the Sopron-Area (Eastern Alps, W-Hungary). Torok, K.

Paragenetic and Fluid Inclusion Data from the Vizcachitas Porphyry Copper Project, Central Chile. Willard, D.T., and Cline, J.S.

The Gas Composition of Inclusions in Accessory Minerals of Barofavourite and Heavy Level Types of Magmatic Complexes of Rocks of Thien Shan. Yusupov, R.G., Polickovsky, V.S., Savarddinov, I.A., and Umarov, B.N.

THE MAGMATIC-HYDROTHERMAL EVOLUTION OF A TIN GRANITE: THE MOLE GRANITE, AUSTRALIA

AUDÉTAT, A., GÜNTHER, D., and HEINRICH C.A. Institute for Isotope Geology, ETH Zentrum/ NO, 8092 Zürich, Switzerland.

A comprehensive understanding of the formation of magmatic-hydrothermal ore-deposits requires the knowledge of all probable parameters controlling the mineralization potential and resulting ore metal ratios of crystallizing melts. The relative importance of factors like oxygen fugacity, abundance of F, B, Cl, S, and H_2O in the melt, depth of magma emplacement, magma temperature and degree of fractionation is still largely unknown. Using advanced fluid and melt inclusion techniques we tried to reconstruct the magmatic-hydrothermal evolution of an intrusion from the very beginning to the very end, i.e. from the moment of magma emplacement to the time when the last quantity of magmatic fluid left the remaining melt and got mixed with meteoric water.

The Mole Granite has been chosen for this purpose because it represents a typical member of tin granites, is strongly mineralized and shows a well-developed regional zoning from Sn-deposits in the center, through W-deposits near its margins, and base metal deposits in the adjacent country rocks. Particular attention has been paid to the study of fluid inclusions and recrystallized melt inclusions, using inclusion petrography, microthermometry, high-temperature melting experiments and quantitative analyses by LA-ICP-MS and electron microprobe. Quantitative reconstruction of the fluid evolution in several vein deposits and in miarolitic cavities, together with analyses of different generations of melt inclusions leads to an integrated picture of the relationship between the magmatic and hydrothermal evolution of the Mole Granite.

A first generation of silicate-rich melt inclusions occurs on concentric growth zones within quartz phenocrysts and contains between 2 and 100 times higher concentrations of Cl, F, B, Li, Cs, W, Sn, Bi, Sb, As, and Ag than whole-rock analyses, whereas most other elements do not differ from the bulk analyses by more than a factor of 2. A second generation of melt inclusions can be found together with primary vapor inclusions (and probably highly saline brine inclusions) in quartz crystals in miarolitic cavities as well as in magmatic topaz. These inclusions reveal extremely low first melting temperatures (<500°C), and homogenization temperatures between 700°C and 740°C. Their composition reflects an extreme degree of fractionation, with a further enrichment of the above listed elements by up to one order of magnitude. A third generation of melt inclusions coexists together with vapor and brine inclusions in outgrown embayment structures in the same quartz phenocryst as generation 1 and have a composition close to the whole rock.

Fluid inclusion studies demonstrate that in the W- as well as Sn-deposits of the Mole Granite ore mineral precipitation was driven by mixing of a boiling, 400–600°C magmatic fluid with 200–300°C meteoric groundwater. In all cases the fluid mixture was additionally enriched in Cu, B, Li, (+ As, Mg, and possibly REE) due to the condensation of magmatic vapor into it. The fractionation of these elements into the vapor phase has been quantified by analyzing coexisting vapor and brine inclusions in several boiling assemblages.

The zonation from Sn-dominated deposits in the granite interior to W-dominated deposits near its contacts seems to reflect an increase in the volatile content of the magma towards the top of the magma chamber. Experimental results and petrographic observations in the Mole Granite suggest that the typical association of mineralization of Sn, W, Bi, Li, and REE with F-rich environment can more readily be explained by an increase in the F-content of the fractionating melt, rather than by fluor-complexing of these elements in the fluid.

HYDROTHERMAL FLUIDS ASSOCIATED WITH INTRUSION-RELATED AU-DEPOSITS WITH LITHOPHILE AFFINITIES: EXAMPLES FROM THE TOMBSTONE PLUTONIC SUITE, YUKON

BAKER, Timothy, LANG, James R., and MORTENSEN, James K. Mineral Deposit Research Unit, University of British Columbia, Dept. Of Earth and Ocean Science, Vancouver, BC, Canada. [t.baker@eos.ubc.ca]

Intrusion-related Au-mineralization characterized by a lithophile metal assemblage of Bi-As-W-Mo±Sn is recognized in several magmatic provinces, and includes significant examples at Kori Kollo, Bolivia (64Mt @ 2.26g/t Au), Salave, Spain (~15Mt @ 2g/t), Kidston, Australia (94Mt @ 1.48g/t) and Fort Knox, Alaska (158Mt @ 0.83g/t). Deposits in this group are genetically associated with reduced I-type intrusions emplaced on the inner (cratonic) side of continental margin arcs or in continental collision settings. Most deposits are hosted by intermediate to felsic, sub-alkalic stocks or plutons. Mineralization styles most common are sheeted veins or breccias, both with low sulfide contents (arsenopyrite and pyrite). Alteration zones are characterized by narrow envelopes of sericite, K-feldspar, albite, quartz and/or carbonate around veins.

The range of characteristics of this class of deposit are reflected in the mid-Cretaceous Tombstone Plutonic Suite which occurs as a narrow belt 700km long extending from SW Northwest Territory, across the Yukon to central Alaska. The belt hosts the Dublin Gulch (50.3Mt @ 0.93g/t), Brewery Creek (17.2Mt @ 1.75g/t Au) and Fort Knox deposits, and includes numerous other occurrences which are currently the focus of exploration. The defining metal assemblage for the belt is Au-W-Bi, with variable As-Sb-Mo-Sn and locally significant Pb-Zn-Ag. Intrusion-related mineralization in this belt is zoned from sheeted Au-quartz vein systems within the intrusion, to W±Au skarns at the intrusion contacts, to sediment-hosted Au and Pb-Zn-Ag veins both within and outside extensive contact aureoles which surround the intrusions.

Fluid inclusion studies have focused on regional definition of fluid types present in addition to more detailed studies of individual deposits. Two major fluid inclusion types are recognized: (1) low salinity (0-6 wt. % NaCl equiv.) carbonic fluid inclusions (Type 4), and (2) halite-bearing (30-40 wt. % NaCl equiv.) aqueous fluid inclusions (Type 3). Secondary liquid-rich aqueous inclusions (Type 1) occur locally whereas vapor-rich aqueous inclusions (Type 2) are absent. Type 4 inclusions are ubiquitous, have CO_2:H_2O which varies from area to area, commonly display evidence of immiscibility and homogenize between 220 and 350°C. Ice melting temperatures are typically depressed by 1 to 4°C below that of pure CO_2 indicating the presence of additional gaseous phases. Type 3 inclusions are locally present, and may contain sylvite, carbonate and sulfide in addition to halite. The majority of inclusions homogenize via halite dissolution (between 200 and 400°C). At the Mike Lake prospect, however, Type 3 inclusions homogenize via vapor loss and coexist with primary Type 4 vapor-rich inclusions, suggesting immiscibility between the two fluids. Pressure estimates based on fluid inclusions suggest depth of emplacement may be a significant control on fluid composition and evolution in the intrusion-related Au-deposits; low pressure systems (~0.5kbar) contain abundant high salinity fluids in addition to ubiquitous carbonic fluids; high salinity fluids occur locally in intermediate pressure systems (~1-2kbar), and generally Type 3 inclusions are absent in high pressure systems (>2kbars).

REEQUILIBRATION OF SYNTHETIC CO_2-H_2O FLUID INCLUSIONS IN QUARTZ

BAKKER[1], Ronald J., and DIAMOND[2], Larryn W. [1]Geologisch-Paläontologisches Institut, INF 234, D-69120 Heidelberg, Germany. [2]Mineralogisch-Petrographisches Institut, Baltzerstrasse 1, CH-3012 Bern, Switzerland. [ronald.bakker@ urz.uni-heidelberg.de; larryn@mpi.unibe.ch]

Changes in fluid inclusion composition and volume following entrapment are of primary concern in attempts to reconstruct paleo-fluid properties from natural inclusion-bearing samples. It has been convincingly demonstrated by high temperature experiments that molecular H_2 may diffuse into and out of fluid inclusions in quartz, according to the imposed fugacity differentials between the inclusions and their external environment. However, recent experimental investigations designed to test the post-entrapment behaviour of aqueous fluid inclusions in quartz under conditions of differential pressure ($\Delta P \equiv P_{inclusion} - P_{external}$) and differential fugacity of water ($\Delta f_{H2O} \equiv f_{H2Oinclusion} - f_{H2Oexternal}$) have led to a controversy regarding the exchange of H_2O. Bakker & Jansen (Nature 345: 58-60, 1990; GCA 55: 2215-2230, 1991) reported loss of H_2O from homogeneous CO_2-H_2O fluid inclusions subjected to $-\Delta P$ and $-\Delta f_{H2O}$, implying that H_2O migrated out of the inclusions *against* the imposed Δf_{H2O}. Sterner et al. (CMP 119: 1-15, 1995) showed that H_2O migrates into or out of homogeneous H_2O-salt inclusions at $\Delta P = 0$, *down* the imposed Δf_{H2O} gradients.

Our working hypothesis to resolve these contradictions is to suppose that two independent, additive forces drive diffusion of H_2O through the quartz host at a given temperature: one is a response to the gradient in chemical potentials associated with Δf_{H2O}, and the other is a response to wetting of the defects and cracks induced by ΔP. The effects of these forces are coupled inasmuch as gain or loss of H_2O may change internal pressure. We assume that temperature and time play similar kinetic roles, and that CO_2 and NaCl remain immobile.

In order to test these ideas, we have performed two types of hydrothermal reequilibration experiments using synthetic CO_2-H_2O fluid inclusions in quartz, with the aim of discriminating the effects of Δf_{H2O} and ΔP. Starting inclusions with $X_{H2O} = 0.6$ were synthesized at 600°C, 500 MPa from silver oxalate and water and retrieved from the run conditions isochorically. After performing microthermometry and photographic documentation these inclusions were reequilibrated at 600°C for 30 days as follows:

(1) Pure H_2O was used as an external pressure medium to generate $\Delta P = +100$ MPa and $\Delta f_{H2O} = -32$ MPa. The inclusions acquired equidimensional, negative-crystal shapes and $Th_{CO2(L+V\rightarrow L)}$ values increased slightly while $Th_{TOT(L+V\rightarrow L)}$ decreased. From these observations we infer that H_2O migrated into the fluid inclusions *down* the imposed Δf_{H2O} gradient, to reach a maximum X_{H2O} of 0.65. The calculated increase in inclusion volume associated with this process is 7.6%. Either the imposed ΔP had no effect on H_2O exchange, contrary to our working hypothesis, or its effect was overriden by the magnitude of the Δf_{H2O} gradient. The deduced increase in volume is consistent with the summed effects of the ΔP and Δf_{H2O} gradients. Fluid inclusions that had partially decrepitated during first microthermometric heating reequilibrated differently.

(2) Pure H_2O was used as an external pressure medium to generate $\Delta P = 0$ and $\Delta f_{H2O} = -111$ MPa. The inclusions acquired flat, negative-crystal shapes and $Th_{CO2(L+V\rightarrow L)}$ values increased slightly. Until total homogenisation data are available these changes are attributed to either (i) H_2O loss and/ or volume increase, i.e. *against* the imposed Δf_{H2O} gradient and imposed zero ΔP, or (ii) H_2O gain *down* the imposed Δf_{H2O} gradient, with increase in volume driven by the increase in internal pressure.

MAJOR FAULT ZONES IN THE CANTABRIAN ZONE (NW SPAIN): POSSIBLE MIGRATION PATHS FOR PETROLEUM

BAKKER, Ronald J., and GRIMMER, Jörg. Geologisch-Paläontologisch Institut, INF 234, D-69120 Heidelberg, Germany. [ronald.bakker@urz.uni-heidelberg.de; jgrimmer@ix.urz.uni-heidelberg.de]

The Cantabrian Zone has been interpreted as the foreland thrust and fold belt of the Hercynian orogeny in the north-western part of the Iberian Peninsula. Fault breccia from several major thrusts in the Ponga Unit and the Picos de Europa Unit (mainly Carboniferous limestones and Cambrian-Ordovician quartzites) were selected for fluid inclusion research. The objective of this study is to estimate the significance of fluid flow through these fault-zones.

Fault-zones are partly characterized by massive calcite/dolomite mineralization between clasts, whereas other zones are lacking any of these features. Fault breccias indicate a complex sequence of different types of mineralization, with different types of fluid inclusions. Each type has been characterized with microthermometry and fluorescence.

Fluid inclusions appear to have mainly a primary nature in most cements, and the populations consist mainly of all liquid inclusions. Only a small percentage show the presence of a small vapor bubble within the liquid. These properties indicate formation conditions at shallow depths and temperatures below 50°C for all types of cement. In an early and late type of vein mineralization two types of primary water-rich inclusion were observed, i.e. sweat water and 16 eq.wt% NaCl, and intermediate salinities. Within an intermediate cement fluid inclusions show fluorescence, indicating the presence of petroleum fluids. This fluorescence is restricted to this type of calcite cement. Furthermore, fluorescence was detected in some solid inclusions in the vein material and in stylolytes from the host rock.

The results illustrate the presence of at least three different types of fluids which must have been circulating in these fault zones at shallow depths. A brine appeared to be simultaneously present with meteoric water, partly mixing at interfaces and producing intermediate salinities. The presence of a petroleum fluid can be relatively dated from different types of cements. The origin of the petroleum fluids may be of sedimentary origin, as stylolytes also contain organic matter. However, it should not be excluded that these fluids were formed in deeper rock, using these fault zones as migration paths before mineralization completely sealed these zones. These rocks illustrate the twofold characteristic of thrust, i.e. migration path versus seal for fluids.

GENESIS CONDITIONS OF THE BEREZOVSK GOLD DEPOSIT, MIDDLE URALS: EVIDENCE FROM FLUID INCLUSION AND ISOTOPIC DATA

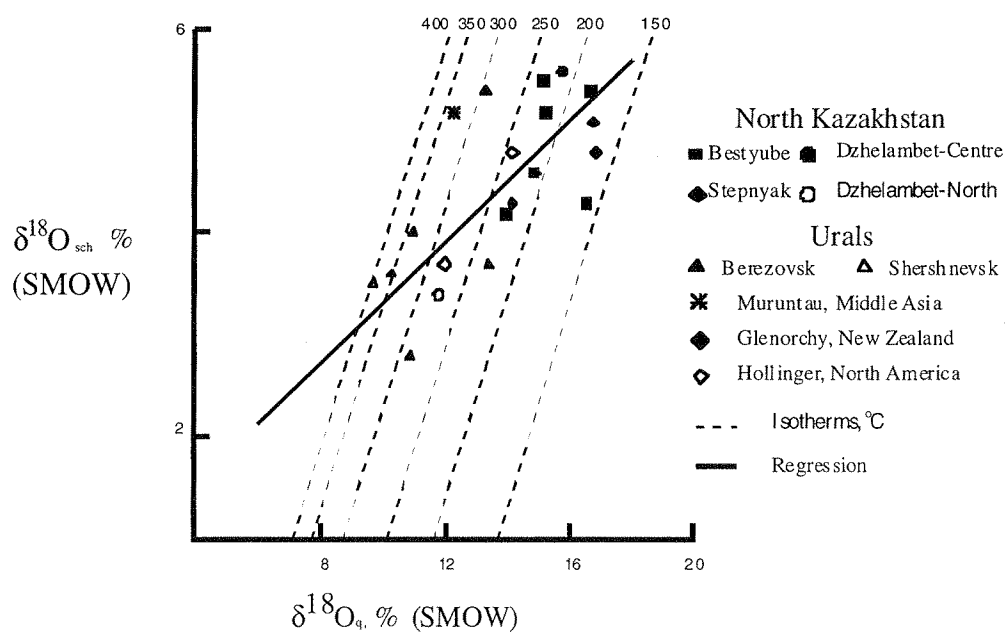
BAKSHEEV[1], Ivan, PROKOFIEV[2], Vsevolod, and USTINOV[3], Vladimir. [1]Department of Geology, Moscow State University, 119899 Moscow, Russia. [mineral@geol.msu.ru] [2]Vinogradov Institute of Geochemistry, Siberian Branch of RAS, Favorsky St. 1a, 664033 Irkutsk, Russia. [3]IGAC RAS, Kosygin St. 9, 117975, Moscow, Russia.

The Berezovsk mesothermal Au deposit is near Ekaterinburg, Urals. The deposit is related to the beresite association and controlled by the systems of granitoid-porphyry and lamprophyre dykes. The volcanogenic-sedimentary host-rock series including numerous small serpentinized ultramafite bodies are of the S-D age. The series are gently pitching. We studied individual primary fluid inclusions (FI) from gangue quartz and scheelite from ladder veins of the deposit and oxygen isotopic composition of these minerals. Quartz and scheelite are formed by CO_2-rich NaCl-$MgCl_2$ solutions ($T_{eutec.}$ -28 to -37°C). Salinity of the solutions ranges from 7.3 to 17.0 wt.% eq NaCl, temperature 270-350°C, pressure 1.4-3.5 kb.

By mineralogical data in the ladder veins two generations of gangue quartz occur. Earlier quartz-I forms close intergrowths with scheelite; later quartz-II forms close intergrowths with fahlore and aikinite which are typical minerals for the productive assemblage. Homogenization temperatures of FI from quartz-I range from 320 to 350°C, of scheelite from 310 to 335°C, and of quartz-II from 270 to 300°C. Quartz-I has a higher concentration and wider range of CO_2 than that for quartz-II. They are 3.1-6.3 and 3.1-5.3 mole/kg of solution, respectively. C_{CO2} and C_{CH4} from the quartz-I FI have a direct correlation. Salinity of fluid responsible for the quartz-I formation is lower than that for quartz-II. They are 9.2-15.1 and 9.4-17.0 mole/kg of solution, respectively. Pressure at the quartz-I formation was ~2.5 kb, at the quartz-II formation ~2 kb.

A direct correlation between $\delta^{18}O$ of quartz-I and scheelite at the Berezovsk deposit and other mesothermal Au deposits has been established (Fig.). It indicates the equilibrium crystallization of these minerals.

Thus, the Berezovsk ladder veins were formed during at least two pulses of hydrothermal activity. The calculated values of oxygen isotopic composition of fluids responsible for the formation of both quartzes ($\delta^{18}O_{H2O}$=3.6-6.5%) and scheelite ($\delta^{18}O_{H2O}$=2.8-5.4%) indicate the magmatic and/or metamorphic sources for them.



UNUSUAL LOW TEMPERATURE PHASE BEHAVIOR IN THE SYSTEM H_2O-NaCl-$FeCl_2$

BALDASSARO, Paige M., and BODNAR, R.J. Virginia Tech, Fluids Research Lab, Blacksburg, Virginia 24061-0420.

The low temperature phase behavior of the system H_2O-NaCl-$FeCl_2$ was examined using synthetic fluid inclusions. Known amounts of solid $FeCl_2$-$4H_2O$, solid NaCl and distilled water were loaded into gold capsules containing a fractured quartz core and a known amount of solid buffer, Fe^0. In addition to synthetic fluid inclusions, sealed micro-capillaries were used to further constrain the low temperature behavior. All experiments were conducted along the 5 wt% NaCl isopleth with $FeCl_2$ concentrations of 5, 7, 18, 31 and 49 wt%. The capsule was loaded into a cold-seal pressure vessel and run at 600°C and 3 kbar for 5-7 days. The buffer, after the experiment, was completely oxidized to magnetite and the liquid released from the capsule upon opening was always clear initially, but would turn yellow to orange over a short period of time after contact with atmospheric O_2. This provided further indication that the contents within capsule remained reduced during the experiment.

Borisenko (1977, Geologiya i Geofizika, 18(8):16-27) reported a eutectic temperature of –37.0°C for the system H_2O-NaCl-$FeCl_2$. However, in this study, liquid was observed at ~-40°C for a composition of 7 wt% $FeCl_2$ and was also observed at -48.2°C for a composition of 18 wt% $FeCl_2$.

For compositions between 0-25 wt% $FeCl_2$, anomalous reproducible phase behavior was observed. After freezing, the inclusions were heated until one crystal remained. The inclusions were then cooled very rapidly to -197°C. It was expected that the solid would completely fill the inclusion and enable the eutectic temperature to be more easily determined, especially at low salt concentrations. However, at some temperature above -197°C, before completely filling the inclusion, the crystal stopped growing. The remaining components in the system, solid, liquid and vapor, showed no observable change until the inclusion was heated. The temperature at which the solid started to melt upon heating varied with the amount of surface area of liquid in contact with solid. The amount of solid generated upon cooling varied with composition, the higher the $FeCl_2$ concentration, the less solid grew.

A fluid inclusion with a composition of 18 wt% $FeCl_2$ was cycled until one crystal remained in the inclusion. The inclusion was quickly heated from -197°C to -80°C and then slowly heated at a rate of 20 degrees per minute. At –72.5°C, another crystal nucleated from the remaining liquid. It did not fill the remaining inclusion despite repeated cycles of cooling and heating at various rates.

Above 25 wt% $FeCl_2$, the inclusions displayed a different type of unusual phase behavior. This concentration is high enough that a significant volume of liquid should be produced at first melting. However, the inclusions did not freeze, even when cooled to -197°C. No glass phase similar to that reported by Roedder (1984, Rev. Mineral.:12, 644 pp.) for other systems was observed. Upon heating, either slowly or quickly, no phase transitions were detected, as would be expected when the glass transforms into the crystal phase that is stable at that composition.

FLUID INCLUSIONS IN HALITE INDICATE EXTREMELY ACID PERMIAN LAKES AND GROUNDWATERS

BENISON[1,2,3], Kathleen Counter, GOLDSTEIN[1], Robert H., WOPENKA[4], Brigitte, BURRUSS[5], Robert C., and PASTERIS[4], Jill Dill. [1]University of Kansas, Lawrence, KS. [2]Kansas Geological Survey, Lawrence, KS. [3]present address: Central Michigan University, Mt. Pleasant, MI. [4]Washington University, St. Louis, MO. [5]United States Geological Survey, Reston, VA.

During the mid Permian, saline lakes, pans, and mudflats deposited bedded halite and red-bed sediments over an area of at least 200,000 km^2 of the North American midcontinent. Laser Raman microprobe (LRM) analyses of fluid inclusions in bedded and displacive halite from the Opeche Shale of North Dakota and the Nippewalla Group of Kansas show peaks for bisulfate (HSO_4^-), in addition to peaks for sulfate (SO_4^{2-}) and water. LRM analyses of standard solutions of widely ranging pH in the subsystems of $NaCl$-Na_2SO_4-H_2SO_4-HCl-H_2O indicate that only waters with pHs below 1 are characterized by Raman spectra with one or more bisulfate peak. Therefore, bisulfate peaks in LRM spectra of fluid inclusions in natural halite are evidence for highly acid ($pH < 1$) Permian lake waters and groundwaters. Fluid inclusion leachate analyses by ICP-AES and ion chromatography show that these were Na-K-Mg-Ca-Cl-SO_4-rich brines with relatively high concentrations of Al, Si, and Fe, also characteristic of modern acid waters. This marks the first identification of ancient acid lake systems.

Natural acid lake and groundwater systems throughout southern Australia may be modern analogs for ancient acid waters. Both the modern Australian and the Permian acid systems are characterized by shallow saline lakes in red siliciclastic sediments. This discovery of ancient acid waters should have far-reaching implications for better understanding the ecology of lake systems, water budgets of past climates, chemical evolution of lake waters and groundwaters, and formation of red beds.

FLUID INCLUSION MICROTHERMOMETRY IN Be-Ta-(Li-Sn) BEARING PEGMATITES FROM THE BORBOREMA PROVINCE, NORTHEAST BRAZIL[1]

BEURLEN, Hartmut, da SILVA, Marcelo R.R., and de CASTRO, Cláudio. Depto. Eng. de Minas, UFPE, Rua Acad. Hélio Ramos s.n., 50.740-530, RECIFE-PE, BRAZIL. [1]Supported by the CNPq Grants 523401/94 and 520053/96.

Fluid inclusions (FI) in Be-Ta-Li-Sn bearing pegmatites reported in the literature are hypersaline aqueous brines, low salinity aqueous or aqueous carbonic fluids. The evolution of volatile fluids in equilibrium with the different phases of pegmatite crystallization do not follow a universal model. This work contributes to this discussion, as well as provides the first FI data from the Borborema Pegmatite Province in Northeast Brazil. Several heterogeneous Be-Ta-(Li-Sn) pegmatites were sampled systematically along cross sections to study the FI in the different pegmatite zones (I- muscovite rich contact zone, II- homogeneous or graphic pegmatite, III- blocky feldspar zone and IV- quartz core). The observed FI (mainly in quartz) are mainly secondary or pseudosecondary, grouped along healed fractures with chaotic orientation. FI were either low salinity aqueous or aqueous-carbonic (frequently in trails with silicate daughter crystals, especially muscovite) or rarely pure carbonic fluids. Some well-formed drusy crystals, although nonsystematically chosen, provided primary inclusions for study. Microthermometric data show that the various pegmatite phases were in equilibrium with low salinity, aqueous or aqueous-carbonic fluids, with insignificant N_2 or CH_4, and with common silicate (and probably other) daughter minerals, similar to the secondary FI of the systematic samples. The fluid apparently evolved from carbonic [CO_2 (50%) fluids in equilibrium with graphic pegmatite and early minerals (beryl, manganotantalite, blue tourmaline of zones II and III)] to low-carbon aqueous fluids (in the core of quartz crystals at the limit between zone III and the quartz core) to CO_2-free aqueous fluids in the border of these crystals and in minerals of the replacement bodies (apatite, euclase). In one single quartz crystal a thermal gradient of 150°C from the smoky core (Th 290°C, low CO_2, low salinity, aqueous) to the hyaline border (Th 144°C, aqueous, moderate salinty) was measured. The salinity in this crystal oscillates in successive growth zones suggesting formation in an open system. A similar evolution from aqueous carbonic to low salinity aqueous fluids has also been observed in several pegmatite provinces throughout the world.

Host minerals, (zone), Pegmatite name	type	vol %H_2O	vol % CO2	Tm(ice)	Tm (clath)	Th
Quartz from graphic pegmatite (zone II) Boqueirão,Mamões & Ubaieiras	AC±S C A±S	20 - 80 0 100	80-20 100 0±S	 -3.0±1.5	3.0 - 8.0	150-310 20-30 150-250
Double colored tourmaline, (zone II), Boqueirão	AC±S A±S	50 100	50 0	 -3.0±1.0	6.0 - 8.0	decrypt. 150-220
Morganite, (limit zone II and III), Mamões	A±S	50	50		8.5±0.3	321±3.0
Manganotantalite, (Zone III), Mamões	A±S	30 - 60	70 - 40		9.0±0.2	288±12
Quartz, (limit Zone III and IV), Boqueirão, Th decrease systematically from 290°C at the core to 150°C at the rim)	A±S(RIM) AC±S A±S(CORE) A±S	100 >90 100 100	0 <10 (vapor) 0 0	-2.1(0.7 -3,0±0.5 -3,0±0.4 -9.5±1.7	3.5 - 8.5	144±12 210±17 289±15 187±17
Quartz with euclase overgrowth Zone IV or replacement body Mamões	AC±S A±S A±S	>90 100 100	<10 0 0	 -3.0±1.0 -10.0±5,0	5.0 -8.0	180-210 190±15 180±16
Apatite from replacement body, Alto Feio	AC±S	>90	<10	2.2±0.3	9.8±0.2	249±23
All samples	secondary,A±S secondary,A±S	100 100	0 0	-0.5 - 2.0 -10.0±5.0		130-200 130-200

Obs.:A = aqueous, C = carbonic; AC = aqueous-carbonic; ±S = with frequent daughter minerals, mainly muscovite.

A MODEL FOR THE TEMPORAL AND SPATIAL EVOLUTION OF MAGMATIC FLUID INCLUSIONS IN PORPHYRY COPPER DEPOSITS

BODNAR, R.J. Fluids Research Laboratory, Virginia Tech, Blacksburg VA 24061.

The fluid inclusion characteristics of porphyry copper deposits have probably been studied in more detail than any other single ore deposit type. As a result of these studies, we have a large amount of information concerning the variability in fluid inclusion microthermometric behavior in these deposits. Various workers have interpreted these data to determine the PVTX characteristics of magmatic and later fluids responsible for mineralization and alteration. Thus, although a wealth of data exists on the types of fluid inclusions present in porphyry copper deposits, and these data have been used to characterize the magmatic fluids in the deposits, a complete understanding of the types of magmatic fluid inclusions that *should* exist in these deposits is lacking. As a first step in a larger effort to develop a quantitative fluid flow model describing the evolution of magmatic fluids in porphyry copper systems, the characteristics of fluid inclusions trapped during crystallization of a porphyry copper-type "Burnham melt" have been calculated.

Following the Burnham model for crystallization of a granodioritic magma emplaced at sub-volcanic levels, the PVT properties of a magmatic fluid with a composition of 10 wt.% NaCl have been calculated. The model assumes hydrostatic pressure conditions from the surface down to the 400°C isotherm, and lithostatic pressure conditions below that depth. Early in the crystallization history, fluids exsolved from the magma are in the two-phase liquid + vapor field and produce the coexisting halite-bearing and vapor-rich inclusions that are characteristic of these deposits. Surprisingly, the model predicts a "pod" in the upper portions of the magmatic system that is within the vapor + halite region of the H_2O-NaCl system. Inclusions trapped here result in coexisting vapor-rich and halite-only (or large halite crystals surrounded by a small amount of vapor) inclusions. Such inclusions have been reported in many porphyry deposits but their significance has not been understood. A vapor-only zone occurs along the pluton margins at depth during this early stage of crystallization.

During the intermediate stages of crystallization, the liquid + vapor field expands downward as the magma crystallizes. The vapor + halite field remains at shallow levels, and the vapor-field along the side of the pluton expands upward.

During the latest stages of crystallization, the liquid + vapor region shrinks considerably and is replaced by a large vapor field along the sides of the pluton. This vapor field extends upward over top of the pluton and completely envelops the liquid + vapor field. At shallower levels, the vapor field grades into the liquid field without crossing a phase boundary. Thus, magmatic fluids exsolving from the pluton late in its crystallization history would have a salinity of 10 wt.% NaCl. These fluids could migrate from this deep vapor field at magmatic temperatures upward into a lower temperature liquid region without experiencing immiscibility. Inclusions that trap this fluid would be liquid-rich at room temperature and would homogenize in the 300-470°C range. Such moderate salinity inclusions observed associated with phyllic alteration in porphyry systems have been interpreted to be of meteoric or mixed magmatic/meteoric origin, but model results suggest that such fluids are consistent with a magmatic origin.

Results of this study suggest a systematic evolution in magmatic fluid inclusion properties during crystallization of porphyry-related magmas. The predicted PVT behavior of fluid inclusions is consistent with the vapor plume model of Henley and McNabb. The model further suggests that late-stage, moderate salinity, moderate temperature fluid inclusions are a natural consequence of magmatic fluid evolution, supporting earlier suggestions that similar fluids associated with phyllic alteration in porphyry deposits are of magmatic origin.

3D GEOMETRY RECONSTRUCTION AND P-V-T-X CONDITIONS OF MICROFISSURAL ORE FLUID MIGRATION IN CRYSTALLINE ROCKS: THE EXAMPLE OF THE MOKRSKO Au-BEARING GRANODIORITE (BOHEMIAN MASSIF).

BOIRON[1], Marie-Christine, BARAKAT[1], Ahmed, CATHELINEAU[1], Michel, BANKS[2], David, DURISOVA[3], Jana, and MORAVEK[4], Petr. [1]CREGU and UMR G2R 7566, BP23, 54501 Vandoeuvre-les-Nancy Cedex, France. [2]Department of Earth Sciences, Univ. of Leeds, Leeds, UK. [3]Czech Geological Survey, Praha, Czech Republic. [4]AUREA, Jilové u Prahy, Czech Republic.

Study of the 3D geometry and P-V-T-X conditions of fluid migration in crystalline rocks shows that the circulation of fluids may occur through a dense and regular network of extensional structures. Integrated studies including 3D reconstruction of the geometry of fluid pathways (veins, veinlets, fluid inclusion planes network) using video-image analysis, SEM with cathodoluminescence, and the P-V-T-X properties of fluids through multidisciplinary studies of fluid inclusions (microthermometry, Raman spectroscopy and bulk ion chemistry) have been carried out for fluid percolation in the Mokrsko-Celina district (Bohemian Massif, Czech Republic). This type of study appears beneficial for developing a genetic model of fluid circulation and ore formation in the case of gold mineralisation.

The largest gold deposit in the Bohemian Massif, the so called Mokrsko-Celina, has exceptional ore textures, especially a dense set of subparallel gold-bearing quartz veinlets. Ores result from the superposition of three main stages of fluid migration through a series of dense and regular sets of extensional structures (veinlets and microfissures).

- The early stage is characterized by the formation of thick parallel quartz veins and then by regularly spaced tension gashes filled by quartz, pyrite, pyrrhotite and arsenopyrite, under a subE-W compression with sub-horizontal $\sigma 1$. Fluids belonging to the C-H-O-N system probably result from interactions with metamorphic rocks under high P-T conditions ($T \approx 450\text{-}550°C$ and $P \approx 250\text{-}400$ MPa). Fluids have strongly interacted with the vein wall-rocks, partially altering amphiboles and biotites I to secondary biotites (±microcline), and precipitating sulfides (pyrite, arsenopyrite) frequently at the contact with Fe-Mg silicates.

- Tension gashes and the granodiorite are in turn affected by a succession of brittle deformation events responsible for the development of subE-W striking microfissure sets filled by pyrrhotite, chalcopyrite and galena. Associated fluids are enriched in volatile species, and were trapped under relatively high pressure and high temperature (300-420°C and 100-200 MPa).

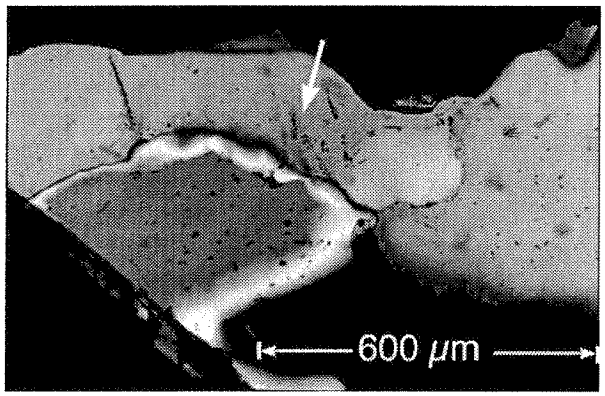
- The last stage is characterized by intense microfracturing of the rock which results in dense sets of subN-S striking fluid inclusion planes (FIP) which cut all previous structures. These FIP contain aqueous inclusions having low salinity (< 8 wt. % eq. NaCl), and trapped at low pressures (< 70 MPa) and temperatures (220-280°C). Gold particles occur in microfissures affecting earliest sulfides intimately associated with Bi-minerals and chlorites (± carbonates). Thus it was enriched or introduced at the end of the main ore stage from fluids surrounding the pluton thanks to a microfissural permeability formed after the silicification of the granodiorite, especially by the preferential fluid circulation in the most competent units ("silicified" granodiorite). Thus, Au-ores are geometrically controlled by the superposition of the deformational events in the same place.

Quartz from an early thick quartz vein and from the main veinlets has been analysed by crush leach techniques. In both samples, the dominant anion is Cl, SO_4 being minor but significant. Fluids from the quartz veins are dominated by Na, Ca and sometimes appreciable Fe, Mn. Br/Cl from quartz veinlets ranges from 0.0013 to 0.0021 while the thick quartz veins have Br/Cl around 0.0040. There is no difference in the I/Cl ratios between the fluid inclusions from the two types of quartz. Fluids from the pre-ore stage quartz vein display a halogen signature similar to those obtained on other magmatic fluids. The halogen ratios of the fluids from the quartz veinlets are quite similar to those observed for the fluids associated with gold mineralization in Iberia (Boiron et al., 1996, GCA 60:43-57) and can be interpreted as indicating they were derived from deep percolation of surface waters which equilibrated with crustal rocks under high P-T conditions.

FLUID INCLUSIONS AS A MONITOR OF PROGRESSIVE GRAIN-SCALE DEFORMATION DURING COOLING OF THE PAPOOSE FLAT PLUTON, EASTERN CALIFORNIA

BRAUER, Nancy A., BODNAR, R.J., and LAW, R.D. Virginia Tech, Fluids Research Lab, Blacksburg, VA 24061-0420.

Analyses of fluid inclusions and microstructures within the Papoose Flat pluton were used to investigate the temperatures of fluids circulating with the pluton during cooling. Based on previous microstructural analyses, the interior of this late Cretaceous granitic to granodioritic pluton has been divided into three domains: i) a central core characterized by magmatic microstructures, ii) a middle domain of high temperature (>500°C) solid-state deformation, and iii) an outermost domain characterized by relatively low temperature (<500°C) solid-state deformation. Microstructural analysis of samples from all three domains confirmed the transition from magmatic flow in the core of the pluton to solid-state deformation at the pluton margin. However, weakly developed solid-state microstructures overprint the dominant magmatic microstructures in samples from the core domain. The existence of solid-state microstructures in all three domains indicates that deformation continued during and after crystallization of the interior of the pluton.



Two phase, low salinity (< 26 wt% NaCl equivalent), liquid-rich aqueous fluid inclusions predominate within both quartz and feldspar grains in all samples. Throughout the pluton, the majority of fluid inclusions are hosted by deformed grains. Feldspar-hosted primary inclusions are associated with sericitic alteration. Inclusions were also observed in feldspar as secondary or pseudosecondary inclusions along fractures. Inclusions in quartz are frequently found near lobate grain boundaries or near triple junctions. The white arrow in the figure (cross polarized light) indicates an area of linear pseudosecondary inclusion assemblages in quartz that has recrystallized by grain boundary migration. The assemblages are thought to mark the positions of healed microcracks which have been partially overprinted by migrating grain boundaries, and indicate that discrete microcracking events occurred during plastic deformation.

Homogenization temperatures overlap for all three microstructural domains. The mineral assemblages of the contact aureole and the pluton indicate trapping pressures between 3.8 and 4.2 kb. Ninety-eight percent of the calculated fluid inclusion trapping temperatures (Tt's) at 3.8 - 4.2 kb are below the granite solidus of 650°C. Seventy-six percent of the Tt's fall within the more restricted range of 350-500°C; i.e. at temperatures which are lower than the commonly cited brittle-ductile transition temperatures for feldspar at natural strain rates, but above those for quartz. No correlation could be established between Tt's and either host mineral or microstructural domain within the pluton.

The similar, relatively low Tt's indicate that the majority of inclusions preserved in all three domains were trapped during the late low strain magnitude stages of solid-state deformation. The most common fluid inclusion Tt's (400-500°C) in all three microstructural domains are similar to the deformation temperatures indicated by microstructures and crystal fabrics in the outer part of the pluton; these Tt's are lower than temperatures associated with contemporaneous solid state and magmatic flow in the pluton interior. The similar Tt's within the pluton core and margin must indicate that the final inclusion-trapping event migrated inward from the margin to the core of the pluton as it cooled, because fluid inclusions would rapidly equilibrate to a density appropriate for the PT conditions of their host minerals.

FLUID AND THERMAL HISTORY OF AN EXHUMED PETROLEUM RESERVOIR

BRENNAN, Sean T., and GOLDSTEIN, R.H. University of Kansas, Department of Geology, 120 Lindley Hall, Lawrence, KS, 66045.

The purpose of this study is to determine the fluid and thermal histories of an exhumed petroleum reservoir, El Abra Limestone of the Sierra el Abra, by integrating the record of fluid inclusions (FI) and carbonate diagenesis from one quarry in the Sierra el Abra.

There are three types of cements in this reservoir: calcite precipitated during burial, fracture-filling calcite, and stylolite-related megaquartz. In both calcite cements, FI are secondary and 90% are hydrocarbon in composition (HC-FI). 70% of the HC-FI are liquid-rich and fluoresce one of three colors: blue-white, yellow-white or dark-blue. Some non-fluorescent HC-FI are brownish, single phase, secondary in calcite or primary in megaquartz. Others are colorless, two-phase and are dominated by either liquid or gas. The gas-rich HC-FI homogenize to gas, and the liquid-rich HC-FI homogenize to liquid. The HC-FIAs (fluid inclusions assemblages; Goldstein and Reynolds, 1994) have mean Th values that range from 70 to 115°C. HC-FI have not been altered by leaking or stretching. Aqueous FI are two-phase and liquid-rich with Th values ranging from 95 to 160°C, and Tm ice values that range from -1.6 to -0.4°C. These aqueous FI have been stretched, indicating that the reservoir has been heated to temperatures possibly as high as 160°C. Planes of secondary aqueous FI cross-cut the planes of HC-FI, indicating entrapment of aqueous FI after the reservoir had been charged with oil.

The fluid inclusion and diagenetic observations indicate a complex fluid history. The two-phase HC-FI indicate that different types of hydrocarbon fluids were present. If the various compositions are due to multiple events of migration, then either there were different sources for the various fluids, or the hydrocarbons came from a single source, and were maturing due to changing thermal conditions. Alternatively the change in composition could have occurred in the reservoir. The dark, single-phase HC-FI and bitumen indicate some in-situ alteration of the hydrocarbons.

It is difficult to interpret why there is such a large range for the mean Th values in the HC-FIAs. Potentially, the HC-FI could have been trapped at approximately the same temperature, and the range of HC-FIA mean Th values could be a result of pressure correction with varying degrees of gas saturation in the hydrocarbon fluids. Or, the HC-FI could have been trapped at different temperatures. In either case, based on the various types of hydrocarbon fluids that were in the reservoir, there must have been several fracturing and migration events. One of the non-fluorescent FIA's has evidence of heterogeneous entrapment with liquid-rich and vapor-rich HC-FI that homogenize at the same temperature (110°C). The homogenization temperatures of such FIAs require no pressure correction, and Th is equal to the entrapment temperature (Tt). The aqueous FI suggest that the reservoir might have been heated to at least 160°C after the HCs migrated into this system. Furthermore, the dark brown HC-FI indicate a degradation of the HCs in the reservoir. Primary dark HC-FI in megaquartz, which is observed only in stylolites and stylolite-related fractures, indicate that the HCs had been degraded during further burial resulting in stylolitization. Therefore, HCs migrated into this reservoir prior to maximum burial and in association with fracturing, and were degraded during or after further burial and prior to or during stylolitization.

Based on other studies in this region (Suter, 1984, Yurewicz, et. al., 1997) the general timing of the thermal and fluid events can be determined. The onset of Laramide-related thrusting, which created the fracture system in this region, was between 66 and 61 Ma (Suter, 1984). Illite to smectite transformation data and apatite fission track data from samples, taken from a unit directly overlying El Abra Limestone, indicate that the reservoir was heated to between 80 and 120°C approximately 50 Ma and was cooled below 100°C approximately 30 Ma (Yurewicz, et. al., 1997). Therefore, hydrocarbons first entered the reservoir from approximately 61-50 Ma, the reservoir was then buried and heated, perhaps to at least 160°C. During or after this burial, the HCs were degraded and stylolites formed. The reservoir then cooled to temperatures below 100°C 30 Ma. Therefore, based on evidence from this and other studies, the timing of hydrocarbon migration, maximum burial, heating and hydrocarbon degradation, can be constrained.

GEOCHEMISTRY AND DAUGHTER MINERALOGY OF LATE-STAGE CARBONATITIC FLUIDS: IMPLICATIONS FOR REE, Ba, Sr, U, AND BASE METAL MINERALIZATION PROCESSES ASSOCIATED WITH CARBONATITES

BUEHN[1], B. and RANKIN[2], A.H. [1]Institut fur Geowissenschafen, Universitat Giessen, Germany. [2]School of Geological Sciences, Kingston University, Kingston Upon Thames KT1 2EE, UK.

Carbonatites and associated alkaline rocks typically contain high concentrations (ore grade) of a number of economically important metals and minerals including the REE, Nb, Fe, P, Th, U, $BaSO_4$, $SrSO_4$, CaF_2, and, less typically, base and precious metals. Ore-forming processes in carbonatitic systems are relatively poorly understood, partly because of the complexity and unusual chemistry of the fluid inclusion populations preserved and partly because of the multistage processes generally accepted for the evolution of carbonatitic magmas and fluids.

Associated with the Kalkfeld carbonatite complex, Namibia, we have identified a particularly well preserved and varied assemblage of fluid inclusions in recrystallized quartzites adjacent to the main carbonatite complex. The inclusions show an extensive range of compositions and densities from moderate to high salinity aqueous $NaHCO_3$-NaCl brines and low density CO_2 fluids through to high density daughter-mineral-rich 'melt' inclusions containing up to 90% solids. We interpret these assemblages mainly as a consequence of heterogeneous entrapment of high density carbonatite melts, brines and CO_2 vapor phase. Microthermometric data are difficult to acquire and interpret due to bulk decrepitation of the samples at around 350 to 400°C.

Daughter minerals have been geochemically characterized using a combination of synchrotron micro-XRF and SEM-EDAX. Those positively identified include nahcolite, halite, sylvite, calcite, apatite, fluorite, cryolite, sulphides and arsenides of Fe, Cu, Pb and Zn, rouvilleite $Na_3Ca_2CO_3$ and burbankite $(Ca,Na)_3(Sr,REE,Ba)_3(CO_3)_5$. Thorium and uranium have also been detected in significant amounts by micro-XRF but it is difficult to ascribe these to specific daughter minerals.

The REE patterns of the burbankite daughters mimic the strong LREE enrichment patterns typical of carbonatites. Total REE contents of this mineral phase are of the order of 10%. In many 'melt' inclusions this phase can occupy over 50% of the inclusion volume suggesting that the evolved carbonatitic 'melts' are considerably enriched in REE, Ba and Sr. The widespread occurrence of fluorine-bearing daughter minerals suggests that the 'melt' is strongly enriched in fluorine, supporting the idea that the high REE solubilities inferred (several wt.%) are primarily a consequence of REE-F complex formation. In the Kalkfeld complex, $BaSO_4$, $SrSO_4$ and the REE mineralization is relatively minor but in other complexes (e.g. Bayan Obo, China and Kangunkunde, Malawi), where the surrounding country rocks are enriched to ore grade, they are commonly associated with fluorite. The present results demonstrate the importance of residual carbonatite magmas in the genesis of this important paragenetic association.

Aqueous-rich inclusions are characterized by the water-soluble daughter phases NaCl, KCl and $NaHCO_3$. The common occurrence of Cu-Fe-Zn-Pb sulfide daughter minerals suggests that this aqueous phase is capable of preferentially transporting significant quantities of base metals in carbonatitic environments, primarily as chloride complexes. The generation and focusing of these late-stage, low density, aqueous "carbothermal" fluids evolved from a REE-bearing carbonatite magma not only explains why many carbonatites are enriched in base metals (sometimes spectacularly as in the case of Palabora, RSA), but also why this phase of mineralization is often paragenetically distinct from the more common REE-Ba-Sr-F mineralization.

The salt-poor CO_2-H_2O fluids represented by CO_2-rich, end-member, fluid inclusions, are clearly associated with the metal-bearing carbothermal and carbonatitic fluids, but their precise role in mineralization and metasomatic (fenitisation) processes is presently unclear.

SOLID INCLUSIONS OF HALITE IN QUARTZ: EVIDENCE FOR THE HALITE TREND

CAMPBELL[1], Andrew R., WILSON[1], Sarah A., and DUNBAR[2], Nelia W. [1]Department of Earth and Environmental Science, New Mexico Tech. [2]New Mexico Bureau of Mines and Mineral Resources, Socorro NM 87801.

High-salinity fluid inclusions are common in ore deposits associated with high-temperature magmatic fluids. In halite and sylvite bearing fluid inclusions, microthermometry has, in some cases, documented a decreasing salinity. This has been called the "Halite Trend" (Cloke and Kessler, 1979) and is attributed to halite precipitation from the ore fluid in response to cooling. The halite contains some K in addition to Na. Quan et al (1987) point out that although there is geochemical evidence for halite precipitation, solid inclusions of halite, whose formation would cause the halite trend, have not been reported in the literature.

Vein quartz from the Capitan Mountains, NM hosts halite and sylvite bearing fluid inclusions. These samples exhibit the halite trend on an NaCl-KCl-H_20 triangular diagram. In order to account for this trend the precipitating salt would have had an approximate composition of $(Na_{80}K_{20})Cl$. Halite precipitation is also supported by an increasing Br/Cl ratio from the chemical analysis of the inclusion fluid. No solid inclusions of salt are seen using a transmitted light microscope. However crystals of halite and sylvite have been have been observed with electron microprobe imaging.

The salt crystals were examined by backscatter electron imaging (BSE) for compositional variation and by secondary electron imaging (SE) for topographic relief. Salt crystals were observed in three distinct settings. 1) Salts in direct contact with the host quartz with little topographic relief between the two. These crystals appear to be solid inclusions. 2) Salts located within small pits. These are thought to be either solid inclusions which have partially dissolved during sample preparation, or daughter minerals within fluid inclusions. 3) Radially symmetric lobed salts proximal to a fracture. They sit atop the surface of the quartz and cause bubbling of the carbon coat. These are thought to be precipitated salts from newly decrepitated inclusions due to the vacuum in the microprobe.

Quantitative microprobe analysis of the salt crystals from all three settings show a wide range of compositions in the NaCl-KCl binary. A large number of salt crystals have compositions of around 80 mole percent NaCl. This corresponds to the precipitating halite composition predicted from the microthermometry. The existence, and composition of, the solid inclusions presented here provides evidence for halite precipitation as the origin of the halite trend.

CHEMISTRY OF BRINES MIGRATING AT THE BASEMENT-SEDIMENTARY COVER CONTACT: THE EXAMPLE OF SOULTZ (RHINE GRABEN)

CATHELINEAU[1], Michel, BANKS[2], David, BOIRON[1], Marie Christine, AYT OUGOUGDAL[1], Mohamed, and YARDLEY[2], Bruce. [1]CREGU and UMR 7566, BP 23, 54501 Vandoeuvre-lès-Nancy Cedex, France. [2]Earth Sciences, University of Leeds, Woodhouse Lane, Leeds LS29JT, UK. [cathelin@cregu.cnrs-nancy.fr; D.Banks@earth.leeds.ac.uk]

The Triassic sandstones and their underlying granitic basement of the Rhine continental rift basin near Soultz, France, drilled as part of the European HDR project, have experienced extensive fluid migration since the Oligocene. Fracture sealing (veins filled by quartz or barite) in both formations contain fluid inclusions which provide evidence for downward brine migration from the sedimentary cover to the basement. Thus, a detailed microthermometric, laser-OES, Raman and crush-leach analysis of inclusion fluids has been carried out from the most recent vein fillings to deduce the fluid chemistry evolution from past events to the present-day.

The coarse-grained Triassic sandstones have undergone a silica diagenesis and are then crosscut by fractures filled with barite. The sequence of fluid trapping is the following: i) primary aqueous inclusions in quartz overgrowths, which have salinities around 7-10 wt% eq. NaCl and Th in the 120-130°C range. ii) secondary aqueous inclusions, with salinities of 17-20 wt.% eq. NaCl and Th between 150-190°C, in FIP crosscutting the quartz overgrowths, iii) primary and pseudo-secondary aqueous fluid inclusions with salinities of 2-12 wt.% eq. NaCl and Th similar to present day temperatures 115-130°C and hydrocarbon (HC) rich inclusions in barite veins.

At the top of the granite, fluid inclusions have been studied both in the granite quartz grains (fluid inclusion planes within the magmatic quartz grains) and in barite-quartz veins. In quartz veins from the top of the granite, low Tm ice around -25 to -30°C have been found (Dubois et al., 1996). However, in barite which seems to be the latest mineral to crystallize, Tm ice are between 2 and 14 wt.% eq. NaCl with two distinct modes at 6.5 and 11.5 wt.% eq. NaCl. In granite, very few FIP display features similar to the barite vein fluids. They occur in subvertical FIP striking N170°E, with salinities between 12 and 16 wt.% eq. NaCl, and Th around 140°± 10°C.

The late barites in the basement and its sedimentary cover contain aqueous fluid inclusions with a narrow range of salinities from 9-12 wt. % eq. NaCl, which were trapped at temperatures similar to those of the present day, and characterized by: i) a regular increase in the Na/K ratio with depth, e.g., with increasing temperature (the values range from 8 to 25 and bracket the ratio of the present day fluids); ii) a relatively wide range of Br/Cl ratios from 0.003 to 0.008 indicating the contribution of a Br enriched end-member in fluids percolating through the sediments; iii) Na/Li ratios around 25/40, slightly lower than those of the present day fluids. Na-Cl-Br systematics show that some of the paleofluids are typical of basinal brines which have acquired their chemical features by strong interaction with evaporitic layers.

The fracture system in the Soultz granite and its cover rocks has acted as a pathway for flows of different salinity fluids at different times, evolving towards compositions similar to those present at depth today. The large variations in Cl contents among the studied fluids suggest complex, long-lived and heterogeneous mixing processes between convected low salinity fluids (less than 5 wt.% eq. NaCl) and brines resulting from the water-rock interaction within Triassic formations nearby the sedimentary formation-basement contact. Salinity changes are decoupled from temperature changes suggesting that mixing occurs on the heating part of the fluid cycle. This case study provides significant reference data on the chlorine contents in fluids percolating or stored within basement rocks.

Acknowledgements: This study has been carried out within the framework of the Joule II programme "Fluid behaviour in the upper crystalline crust: a multidisciplinary approach," and the DBT programme "Fluides dans la croûte," and benefited from the support and assistance from SOCOMINE, especially A. Gerard, Director.

NUMERICAL MODELLING OF WATER-ROCK INTERACTION USING RECONSTRUCTED FLUID COMPOSITION: A MULTI-CHARACTERIZATION OF ALPINE FISSURE FLUIDS

CATHELINEAU[1], Michel, GUERCI[1], Alain, BANKS[2], David, BOIRON[1], Marie-Christine, and AYT OUGOUGDAL[1],Mohammed. [1] CREGU and UMR 7566, BP 23, 54501 Vandœuvre-lès-Nancy Cedex, France. [2] Earth Sciences, University of Leeds, Woodhouse Lane, Leeds, UK. [cathelin@cregu.cnrs-nancy.fr; D.Banks@earth.leeds.ac.uk]

The major alpine water-rock interactions observed in and around alpine fissures from granites, e.g. quartz dissolution, crystallization of the main fissure fillings (quartz-chlorite), and later alteration of the previous alteration minerals by an ankerite-muscovite assemblage, have been reproduced using fluid inclusion data and the geochemical code EQ3/6.

Characterization of P-T-V-X features of percolating fluids was obtained through a multidisciplinary study of fluid inclusions including the determination of the temperatures of phase changes using microthermometry, and the quantitative in-situ analysis of gas contents by Raman spectroscopy. The determination of the bulk ion chemistry has been carried out using crush-leach procedures and combined micro-analytical techniques (ion chromatography for halogens, FES, ICP-AES and GF-AA for major and trace elements) of the leachates using the method of Yardley et al. (1993) on 28 representative samples. The main analyzed ions are Na, K, Ca, Mg, Sr, Fe, Cl, Br and F. The individual fluid inclusion chemistry was investigated by laser ablation-OES (Na/K, Na/Li, Na/Ca ratios) and chlorinity by Raman spectroscopy.

Geochemical modelling has been carried out using the detailed compositions from the crush-leach studies and the EQ3/6 code as modified by Komninou (1996). The modifications allow the code to deal with temperatures from 100 to 450°C (0-300°C for the standard version) using two thermodynamic databases generated with SUPCRT92 for pressures of 1kbar and 3kbar (saturated vapor pressure for the standard version).

Quartz dissolution: Along fissures, the quartz is completely dissolved on a scale of a few decimeters. The alteration takes place probably close to 250 MPa and 370°C deduced using isochores and temperature estimations from the K/Na geothermometer. The cause of the undersaturation of the fluid with respect to quartz remains hypothetical, however the most reasonable assumption is to attribute the formation of a H_4SiO_4 depleted fluid to a pressure increase due to pressure cycling (between lithostatic and infralithostatic pressures) during the formation of the veins. The range of Th values is considered to reflect the pressure variation as true temperature was more or less constant at this time.

Quartz precipitation: In fissures, quartz predominates and may be followed by adularia and chlorite (± small quantities of fluorite in some instances). Fluids in both stages are aqueous and display salinities in the range 4-7 wt.% eq. NaCl. Fluctuation in Th within the 160-190°C range is attributed to pressure variation at nearly constant temperature, as shown by the rather constant K/Na ratio of the inclusion fluids. The interaction between a fluid displaying the chemistry of inclusions at Col des Cristaux speciated at 3 kbar and the granite under oxidising conditions at 1 kbar and 370°C produces the mineral assemblage observed in the fissures.

Late alteration: The previous assemblage was altered to a muscovite, Fe-carbonate and quartz (amethyst) association and is related to the input of a CO_2-rich fluid into the vein system. The simulation of the third alteration stage was carried out by adding 1.5 mole of CO_2 per kg to the stage 2 fluid (Col des Cristaux -BP 87-19 type). The resulting fluid was used to react with the quartz-chlorite-(adularia) assemblage at 1 kbar. Results closest to the natural situation were obtained when the temperature was decreased from 370°C to 270°C.

THE GAS COMPOSITION AND TEMPERATURE OF FLUIDS RELATED TO DIAMOND BEARING CARBONATITES, WESTERN UZBEKISTAN

DIVAEV[1], Farid K., POLICKOVSKY[2], Vladimir S., IVANOVA[2], Nina A., and YUDALEVICH[3], Zinoviy A. [1]Inst. Mineral Resources,T. Shevchenko str, 11-a, Tashkent, 700060, Uzbekistan, fax:3712-406812. [2]International Academy of Mineral Resources, Bl.7-47-40, Tashkent, 700096, Uzbekistan, [Mir@Saturn.silk.org] [3]Department of Geology, Ben-Gurion University of Neger, Israel, fax: 972-7-6472997.

Diamond-bearing carbonatites of Southern Nuratau are represented by casenites, ringites, melilitic carbonatites, and rarely siovites, which form dikes and diatremes in enclosing aleuroshists and show no connection to any intrusive massifs. The mineral and chemical composition, the structure and the carbon isotopic composition of carbonatites indicate a mantle genesis for these rocks.

Fluid inclusions in crystals of carbonate and apatite have dimension 0.001-0.03 mm. Primary forms of inclusions are tubular, needle-shaped, drop-shaped, partial faceted, and irregular. The phase composition of fluid inclusions is primary gaseous-fluid, containing 5-35% gaseous phase. Sometimes there are from 1 to more than 4 trapped solid minerals in the fluid inclusions. The chemical composition of the fluid inclusions (CO_2=61.1%, CO=4.8%, CH_4=6.4%, N_2=16.7%, H_2S=1.7%, H_2O=9.3%, average of 5 analyses) is dominated by carbon compounds, with little water, and is taken as evidence for low oxygen fugacities during formation of diamond-bearing carbonatites.

The temperature regime of fluids is characterized by several intervals:

Stage I (late magmatic) - ≥640°C to 480°C
Stage II (autometasomatic) - 440°C to 380°C
Stage III (hydrothermal) - 380°C to 90°C.

Fluid inclusion research on diamond-bearing carbonatites confirms petrologic conclusions about the magmatic genesis of these rocks under the low oxygen fugacity conditions of the earth's upper mantle. We estimate the prospects of carbonatites in Western Uzvekistan as a new source of diamonds as quite good.

THE BOHEMIAN QUARTZ LODE AND ADJACENT VEIN MINERALIZATION IN THE BOHEMIAN MASSIF: AN EXAMPLE OF FLUID CIRCULATION IN A SHEAR ZONE

DOBES[1], Petr, ZAK[1], Karel, LEACH[2], David, and VIETS[2], John. [1]Czech Geological Survey, Klárov 3, 118 21 Prague 1, Czech Republic. [2]U.S. Geological Survey, P.O. Box 25046, MS 973, Denver, CO 80225.

The Bohemian Massif contains Late-Variscan to Post-Variscan hydrothermal minerals and vein-type mineralization (Ag-Pb-Zn, U, Au, fluorite-barite) located predominately in or close to zones of intensive regional shearing or faulting near boundaries of crustal blocks that experienced different uplift histories during the Late-Hercynian period.

The Bohemian Quartz Lode (BQL) is a large quartz lode more than 55 km long and up to 50 m wide and is located in a major NW-SE shear zone along the tectonic boundary between Moldanubicum and Bohemicum Units at the western margin of the Bohemian Massif. Hydrothermal quartz formed late in the development of the shear zone. Several small abandoned polymetallic vein deposits and other smaller quartz veins occur along parallel structures. Another large quartz load called the Bavarian Pfahl is located in Germany and is parallel to the Bohemian Quartz Lode (Peucker-Ehrenbrink & Behr, 1993, Chem. Geol. 103:85-109).

The vein bodies are hosted in migmatitic, cordierite paragneisses and in sillimanite-biotite ± muscovite paragneisses. Near the BQL, rocks underwent a later muscovitization. Quartz in the BQL is of polycyclic origin and shows patterns of dissolution, recrystallization and cataclasis. However, quartz in the parallel Zhor vein show weaker patterns of recrystallization. The Mutenin deposit consists of three massive or brecciated quartz-carbonate (dolomitic-ankeritic composition) veins 0.5 to 0.7 m thick that contain Ag-bearing chalcopyrite and rare bournonite, sphalerite and bornite. The Michalovy Hory ore district consists of a swarm of about 30 steeply dipping, hydrothermal quartz-carbonate veins containing fluorite, barite and a complex suite of Pb-Zn, Ag-Bi-Co-Ni, U minerals.

Microthermometric analyses were performed on quartz deposited from the late mineralizing events of the BQL, on quartz of the Zhor vein, and on quartz and carbonate from selected mineral deposits. Fluid inclusions in all the minerals have variable L:V ratios (LVR), interpreted as the result of continued healing and necking of inclusions at low temperature after nucleation of the vapor phase (Bodnar et al., 1985, Rev. Econ. Geol. 2:73-97) rather than boiling. Th have been measured in small 3D clusters of primary inclusions with consistent LVR. Fluid inclusion data are summarized in the table below. Te and Tm indicate the mixing of low and high salinity fluids of variable Na-K-Mg-Ca-Cl composition. The low Te observed in the latest quartz of the BQL may indicate the presence of LiCl in the fluids. Th did not exceed 210°C.

Measured $\delta^{18}O$ of quartz, δD of hydrothermal kaolinite and sericite, and Th all show that the hydrothermal fluids of the late phases of BQL and of adjacent mineralization had $\delta^{18}O$ values from -5 to +5 ‰ and δD between -60 and -70 ‰ (SMOW) and were neither magmatic nor metamorphic.

Locality	Mineral	Th (°C)	Te (°C)	Tm (°C)	salinity (wt. % NaCl eq.)
Mutenin deposit	carbonate	136 - 148	-52.5	-13.3 to -21.3	17.2 - 23.2
	carbonate	142 - 158	-53.5	-0.9 to -3.8	1.6 - 6.2
	quartz	128 - 165	-53.5 to -56.2	-13.8 to -21.4	17.6 - 23.2
Michalovy Hory deposit					
Wofram vein	quartz	118 - 120	-56.0	-10.4 to -19.2	14.4 - 21.8
	quartz		-46.5	-0.2 to -6.8	0.4 - 10.2
Stare stesti s radosti vein	carbonate	114 - 156	-54.3	-2.1 to -3.2	3.4 - 5.3
Bohemian Quartz	quartz	164 - 182	-37.5 to -38.0	-0.2 to -0.7	0.4 - 1.2
Lode	quartz		-56.5	-11.1 to -20.2	15.1 - 22.5
	latest quartz	138 - 178	-68.0 to -69.2	-20.5 to -31.0	~ 30.0
	latest quartz		-39.6	-2.0 to -2.4	3.4 - 4.0
Zhor quartz vein	quartz	162 - 208	-38.5 to -48.5	-2.6 to -6.1	4.3 - 9.3

THEORETICAL PREDICTION OF PHASE SEPARATION, PVT PROPERTIES, ENTHALPY AND FUGACITY OF SUPERCRITICAL FLUIDS H_2O-CO_2-CH_4-N_2 UP TO 2000 K AND 100 KBAR

DUAN , Zhenhao, MOLLER, Nancy, and WEARE, John. Department of Chemistry 0340, University of California, San Diego, La Jolla, CA 92093-0340.

The equation of state (EOS) of Duan et al. (1992, 1996) was proved able to reproduce thousands of PVT data points for both pure systems and mixtures below 20 kbar from supercritical temperature to about 2000 K. Our recent study found that the EOS predicts all available experimental data, ranging from supercritical phase equilibria, fugacity, enthalpy, and PVT properties up to about 100 kbar for the fluid system H_2O-CO-CH_4-N_2 and their mixtures. This is remarkable because very little data for methane and no data for mixtures above 8 kbar were used in evaluating the parameters in the EOS. Based on the comparison of the EOS with various experimental data, we conclude that the EOS should be applicable for most geochemical studies from about 1.25 times the critical temperature up to about 2000 K and from zero pressure up to about 100 kbar.

ANALYSIS OF METHANE AT LOW CONCENTRATION IN FLUID INCLUSIONS WITH RAMAN SPECTROSCOPY

DUBESSY[1], J., PIRONON[1], J., LAMB[2], W., McSHANE[2], C., POPP[2], B. and THIÉRY[1], R. [1]CREGU, UMR 7566, BP-23, 54501-Vandœuvre-lès-Nancy Cedex, France. [2]Department of Geology and Geophysics, College Station, TX 77843-3115, USA.

The aim of this work is to develop a method for precise determination of isochores of fluid inclusions of the H_2O-NaCl-CH_4 system with low methane concentration for application to diagenetic fluids. This approach is based on a combination of Raman spectrometry and thermodynamic modelling.

Calibration of the ratio of Raman scattering cross-sections of the water stretching mode and the symmetric stretching vibrational mode of methane as a function of temperature and salinity is carried out. Synthetic fluid inclusions have been prepared according to the method of Lamb et al. (1996, GCA 60:1895-1898) in fluorite at 400°C and 5 kbar. Spectra were obtained at different temperatures on a micro-raman spectrometer (Labram, ©Dilor) equipped with a heating stage (© Chaix-Meca) (Fig. 1).

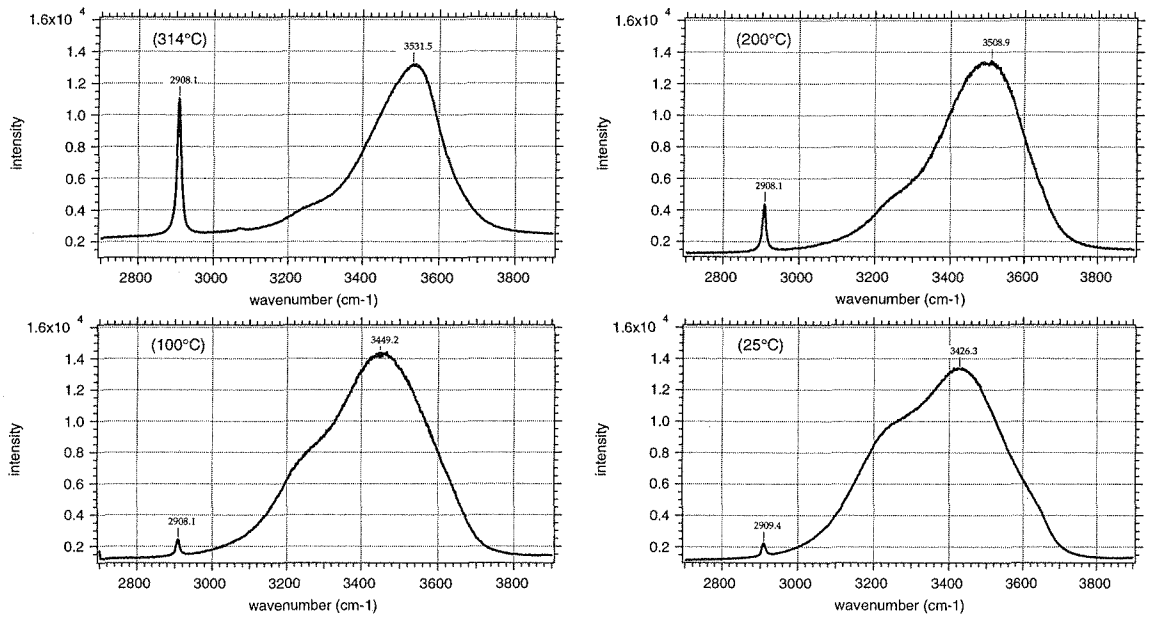


Figure 1. Raman spectra obtained at different temperatures in the aqueous phase of a synthetic fluid inclusion (concentrations in the molality scale: CH_4 = 2.255: NaCl= 1.0).

The stretching band of water shows a decrease of its full width at half height and a shift of its maximum intensity wavenumber. The symmetric stretching Raman band of methane is shifted down by nine wavenumbers with respect to its value for low gas, density but remains constant. The intensity increase of the methane band is related to its increase in concentration in the aqueous phase during increasing temperature to the homogenization temperature. A computer code combining both the Duan et al. model (1992, GCA 56:1451-1460) with mass conservation equations (composition and density) in the inclusion allows the calculation of the concentration of methane in the liquid aqueous solution coexisting with the vapor inside synthetic fluid inclusions as a function of temperature.

The application of Raman data for the calculation of the isochore of natural fluid inclusions of the H_2O-NaCl-CH_4 system is made following the different steps: 1) measurement of the salinity (m_{NaCl}) of the aqueous phase from microthermometric data; 2) determination of the methane molality (m_{CH4}) from the Raman data and the calibration curve established for m_{NaCl}, m_{CH4} and T=Th; 3) calculation of the pressure (Ph) at the homogenization temperature (Th) for the considered isopleth using the Duan model; 4) calculation of the isochore in the single phase region assuming that it is parallel to the isochore of an hypothetical fluid inclusion with the same salinity and same Th.

MULTI-PHASE VEIN SYSTEM AT THE BRONZEWING GOLD DEPOSIT, WESTERN AUSTRALIA: EVIDENCE FOR HOMOGENEOUS T-X CONDITIONS DURING DUCTILE SHEAR ZONE DEVELOPMENT AND FORMATION OF THE VEIN SYSTEM

DUGDALE, Allison L., and HAGEMANN, Steffen G. Department of Geology and Geophysics, Centre for Strategic Mineral Deposits, University of Western Australia, Nedlands-Western Australia 6907, Australia.

The Bronzewing gold deposit is located in the central portion of the Yandal greenstone belt within the Eastern Goldfield Province of the Yilgarn craton in Western Australia. The deposit comprises the distinct Discovery, Central and Western ore bodies with approximately 112 t (3.6 M oz) of contained gold, making it the largest gold deposit discovered in the past 10 years in the Yilgarn craton. The deposit is hosted in greenschist facies tholeiitic metabasalts, with individual lodes controlled by anastomosing ductile shear zones which contain complex, multiphase vein arrays. Preliminary mineral geothermometry suggests temperatures for hydrothermal alteration to be between 300° and 350°C. Cross-cutting relationships and vein textures differentiate three major vein types: (1) tension gash-veins that occur in the distal portion of the ductile shear zones and display only minor hydrothermal alteration, (2) shear and extensional veins that are constrained to the proximal portion of the shear system, and (3) late-stage calcite veinlets that crosscut vein type 1 and 2. Gold mineralization is confined to type 2 shear and extensional veins. Gold occurs predominantly as "free" gold in quartz, and, to a lesser extent, within pyrite.

Quartz veins in the distal portion of the ductile shear zone consist of white buck quartz and contain three types of fluid inclusions: (1) mixed aqueous-carbonic inclusions with highly variable CO_2 and CH_4 content (7 - 93 and 1 - 15 mol %, respectively) and salinity (0.1 - 21 eq. wt.% NaCl). Aqueous:carbonic ratios are variable within trails and clusters; (2) aqueous inclusions of variable salinity (7 to 17 eq. wt.% NaCl); and (3) carbonic inclusions that contain up to 30 mol % CH_4. All three fluid inclusion types are observed in the same trails and clusters, therefore, they form an assemblage, possibly trapped during phase immiscibility.

Shear veins comprise thin quartz bands with interstitial wallrock lamellae. Extensional veins are of two types: (1) composite open space-fill veins, and (2) buck veins that are locally laminated and contain wallrock fragments (implosion breccias). Both shear and extension veins are mostly observed in the proximal alteration zone of the Bronzewing lode-gold deposit. They are an integral part of the ductile shear zone system and contain variable amounts of quartz, carbonate, albite, scheelite, and the majority of pyrite, pyrrhotite and gold. Fluid inclusions trapped in these veins are: (1) mixed aqueous-carbonic inclusions with highly variable CO_2 and CH_4 content (10 - 97 and 0 - 41 mol %, respectively) and salinity (0.1 - 21 eq. wt.% NaCl). Aqueous:carbonic ratios are largely constant, although, locally, the ratio can be variable within individual trails or clusters; (2) aqueous inclusions of highly variable salinity (0.1 to 23 eq. wt.% NaCl), and (3) carbonic inclusions with compositions that range from CH_4-rich (up to 85 mol % CH_4) to nearly pure CO_2. All three inclusion types are observed in the same trail or cluster in most samples, hence they form an assemblage and, therefore, are interpreted to have been trapped contemporaneously. This suggests possible widespread fluid immiscibility at the time of trapping.

This preliminary investigation suggests that fluid immiscibility occurred in both the distal tension gash-veins and the proximal shear and extensional veins. However, the exact nature, and importantly, magnitude of fluid immiscibility remains unclear. Further investigations using laser-Raman spectroscopy and Kd calculations on "boiling-pairs" should constrain the extent of phase immiscibility and its effect on the precipitation of sulfides and gold.

COMPARISON OF LA-ICP-MS AND ION CHROMATOGRAPHY METHODS IN THE ANALYSIS OF SINGLE FLUID INCLUSIONS IN EVAPORITES

ELLENDORFF, Barbara, SCHMIDT, Kai, and SIEMANN, Michael G. Fachgebiet Mineralogie, Geochemie, Salzlagerstätten, Technische Universität Clausthal, Adolph-Roemer-Straße 2A, D-38678 Clausthal-Zellerfeld, Germany. [ellendorff@immr.tu-clausthal.de]

The chemical composition of single fluid inclusions in evaporites yields information on the geochemical evolution of the rock/brine system. Due to the small volumes of most inclusions only one analysis per inclusion is possible by either method.

The two methods for the chemical analysis of single fluid inclusions are compared in their accuracy and precision using inclusions >250 μm in diameter and synthetic standards. The first method is based on the microextraction of single fluid inclusions as described by Lazar and Holland (1988). The brines are diluted and analyzed by ion chromatography (IC). In a single measurement, major and trace elements (Na, K, Mg, Ca, Cl, SO_4, Li, Br) of brines and host crystal can be analyzed accurately.

As a new method for the analysis of single fluid inclusions, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) is employed (Moisette et al., 1996). Different approaches of calibration are discussed. Beside glass standard materials (e.g. NIST SRM 610 and NIST SRM 612) microwells filled with calibration solution are tested.

The microextraction method has already proved to produce reliable data, but it is limited to fluid inclusions >250 μm. Generally, most of the big inclusions are stored in secondary, coarse grained salts, whereas primary salt layers usually contain inclusions which are too small for microextraction. Due to the high dilution factors which are necessary for the determination of major elements by IC, the analysis of trace elements is practically limited to Br and Li.

LA-ICP-MS enables the determination of considerably smaller inclusions and a number of additional trace elements (e. g. B, Rb, Sr) can be studied.

MELT INCLUSION INVESTIGATION OF THE VOLATILE BEHAVIOUR OF FRACTIONATING, ALKALINE MAGMA, MOUNT EREBUS, ROSS ISLAND, ANTARCTICA

ESCHENBACHER[1], A.J., KYLE[1], P.R., LOWENSTERN[2], J.B., and DUNBAR[3], N.W.
[1]Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico, 87801. [2]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California, 94025. [3]New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, 87801.

Mount Erebus is an active, intraplate, alkaline volcano. At present, activity takes the form of a convecting, anorthoclase-phonolite lava lake that is emitting significant amounts of CO_2. The Mount Erebus phonolites are most likely products of progressive fractional crystallization from basanite and phonotephrite compositions similar to the lavas exposed on the flanks of the volcano and adjacent areas.

Melt inclusions in phenocrysts from basanite, phonotephrite and phonolite were analyzed by Fourier transform infrared (FTIR) spectroscopy to determine CO_2 and H_2O concentrations. Melt inclusions in olivine from basanite contain 0.85 ± 0.08 to 1.70 ± 0.15 wt % H_2O and 2704 ± 222 to 6045 ± 431 ppm CO_2 dissolved as carbonate. Inclusions in plagioclase from phonotephrite contain 0.09 ± 0.01 to 0.85 ± 0.09 wt % H_2O and 677 ± 114 to 869 ± 174 ppm CO_2. Melt inclusions in anorthoclase from phonolite contain 0.14 ± 0.01 to 0.38 ± 0.04 wt % H_2O and 533 ± 54 to 843 ± 118 ppm CO_2. These data are consistent with a fractionation trend from basanite to phonolite that is accompanied by continuous degassing and production of a progressively more H_2O-rich gas.

H_2O contents of phonolite and phonotephrite correspond to saturation pressures of 5 to 20 bars and 5 to 100 bars respectively. The concentration of CO_2 in the basanite indicates that it must have begun degassing a CO_2-rich gas at a pressure no less than 2.9 kbar, corresponding to a depth of ~9 km.

LASER ABLATION - OPTICAL EMISSION SPECTROSCOPY (LA-OES): NEW IMPROVEMENTS FOR THE ANALYSIS OF INDIVIDUAL FLUID INCLUSIONS, MINERALS AND GLASSES

FABRE, Cécile, BOIRON, Marie-Christine, DUBESSY, Jean, and MOISSETTE, Alain. CREGU and UMR G2R 7566, BP23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Quantitative chemical analyses of fluid inclusions are a prerequisite for understanding and modelling fluid rock interactions as only these inclusions contain direct evidence of the composition of fluids responsible for past geological processes. Recent developments using laser ablation optical emission spectroscopy (LA-OES) (Boiron et al., 1991, GCA 55:917-923; 1997, XIV ECROFI, Nancy:44-45; Moissette et al., 1997, XIV ECROFI, Nancy:211-212) have shown that this method is adapted for the analysis of the ion content in individual fluid inclusions. The principle is the following: a Nd-YAG laser is coupled with an optical emission spectrometer which analyzes the emission lines of the elements present in the plasma resulting from the interaction between the laser and the material.

New improvements of the apparatus: i) A new holographic grating having a better efficiency in the 500-800 nm spectral range has been installed. Thus, intensities of emission lines for Na (589 nm), Li (670.7 and 613.2 nm), Ca (780.4 and 787.1 nm) and K (766.5 and 769.9 nm) have increased and detection limits for these elements are improved. ii) Sweeping the sample with an argon flow improves the intensity of the emission lines (Mauchien, 1996, pers. comm.). A cell was specially adapted to work under an argon atmosphere. The argon flux has been optimised in order to get the best reproducibility. It has been demonstrated that both low (<0.5 l/mm) and high (> 1.5 l/mm) argon fluxes are inadequate for correct analysis.

Size of the inclusions: Several tests were performed on natural fluid inclusions having various sizes. For big inclusions (> 50μm), at least 50 to 70 shots are necessary to empty the inclusion. However, a reasonable size of inclusion for LA-OES analysis is 20 x 20 μm. With such inclusions, statistic treatment (10 to 20 shots) of emission line ratios is acceptable. In natural inclusions, relative standard deviation (RSD) for Na/Li and Na/Ca ratios are around 10% and 15% respectively.

Calibration and reproductibility: The work has been focused on the 580-780 nm spectral range where Na, Li, K and Ca emission lines can be obtained simultaneously for each shot. Calibrations of element ratios have been carried out on synthetic glasses and synthetic fluid inclusions in quartz. Reproductibility for net intensity of Na, Ca, Li emission lines in glasses is in the range 5 to 15%. In fluid inclusions, RSD element ratios are between 8 and 15%.

Special attention has been paid to the study of Na/Ca ratios and their relationship to microthermometric measurements, especially eutectic temperature. It is noted that inclusions displaying the lower temperature for the first visible phase transition (Tm_1 =-55°C) show the lower Na/Ca ratio. Conversely, for inclusions having Tm_1 closed to -23°C, the Na/Ca intensity emission line ratio is in good agreement with the microthermometric data.

Li emission lines: Li shows a good response in LA-OES. Thus, quantification of the Li content in minerals is possible where no routine technique such as electron microprobe could be used. Li can be analysed from 10 ppm to some % in minerals.

LA-OES appears to be a powerful localized technique for the analysis of major and trace elements at the ppm level in glasses and minerals, and 10-100 ppm in fluid inclusions.

FLUID INCLUSIONS OF THE LA DESCUBRIDORA TIN DEPOSIT: EVIDENCE OF FLUID EVOLUTION

FOGLIATA[1], Ana S., GONZÁLEZ[2], M. Mercedes, and MAS[2], Graciela. [1]CONICET- Univ. Nac. de Tucumán, M. Lillo 205, 4000- S.M. de Tucuman, Tucumán, Argentina. [2]CONICET- Univ. Nac. del Sur. Dpto. de Geología, San Juan 670, 8000-Bahía Blanca, Argentina. [fogliat@csnat.untmre.edu.ar; gonzalez@criba.edu.ar; gmas@criba.edu.ar]

Our aim is to establish PVT properties of the tin-ore forming fluids at La Descubridora, to complement P-T estimates from mineral parageneses. La Descubridora is in Sierra de Mazán, La Rioja province, Argentina, and is part of the Sierras Pampeanas system. It consists of hydrothermal high temperature quartz veins hosted in Silurian-Ordovician granitic rocks, which extend along the contact between these rocks and La Quebrada granite (Carboniferous).

Most veins strike WNW-ESE and dip to the north, are 0.3-3 m wide, and contain quartz, muscovite, pyrite, chalcopyrite and arsenopyrite. Quartz has discontinous undulatory extinction showing moderate deformation. The ore mineral cassiterite is strongly fractured. It appears both within the quartz mass, as coarse aggregates, or with secondary muscovite in the alteration zones as part of a quartz-muscovite-cassiterite type greissen (after Scherba in Smirnov, 1982).

FI in anhedral quartz veins range from <2 to 14 μm. Type I are monophase (L or V) aqueous pseudosecondary and secondary. Type II have two phases: Type IIa are L+V, either isolated or in clusters (primary) or as secondary trails, and Type IIb are V+L, isolated, and condense a low density CO_2 vapor phase on cooling. Type III are primary isolated H_2O+CO_2 with three phases.

Secondary Type IIa FI have a mean Th of 222°C, and primary and pseudosecondary ones have mean Th of 328°C (Fig. 1). The mean Th for Type IIb and III inclusions is also near 328°C, and all FI have around the same salinity of 6 wt% NaCl eq.

Fig.2 (after Hollister and Burruss, 1976, GCA 40:163-175) shows the empirical solvus for CO_2-H_2O with 6wt% NaCl eq., that includes the analyzed fluid molar fraction. The cluster of data points near the experimental curve represents CO_2:H_2O mole fraction. As a whole, the points with higher temperatures fall in the homogeneous area (between 0.06 and 0.1) for Type III and IIb FI, but they are closer to the solvus at lower temperatures. On the other hand, the vapor-rich FI, the aqueous, almost CO_2-free FI and the three-phase FI which homogenized either in CO_2 or in H_2O should represent the unmixing product of effervescence of CO_2 in H_2O. Finally, the secondary aqueous FI and the monophase low density ones would have been trapped even later, clearly in the two-phase field, yielding two fluids of different densities.

A broad span of isochores is a consequence both of varying CO_2 ratios and of a range of temperatures among all types of inclusions.

The mean Th (328°C) can be considered the lowest trapping temperature, and it is concordant with the trapping temperature range proposed by Haapala and Kinnuen (1982) for this kind of deposit. For such a temperature, isochores show a range of pressure varying from 400 to 1400 bars.

The unmixing mechanism which yields monophase and aqueous FI is assumed to have occured between 275°C and 300°C, in the two-phase field.

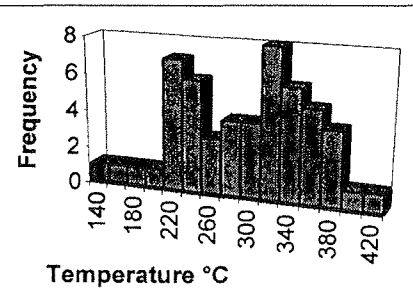


Figure 1: Th (°C) for all fluid inclusions

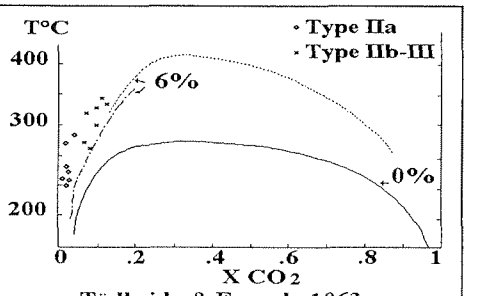


Fig.2: Solvus CO_2-H_2O

POLYCYCLIC AROMATIC HYDROCARBONS (PAH) IN DIAMONDS AND OTHER MINERALS FROM THE KIMBERLITE PIPES OF MIR AND UDACHNAYAVOSTOCHNAYA

GASSYMOVA[1], F.I., and MELNIKOV[2], F.P. [1]Azerbaidzan, Geological Institute SA. [2]Moscow State University.

Exposed hydrocarbon inclusions in zircon (Mir pipe) are similar in their chemical compound to hydrocarbon in such minerals as olivine from the Udachnaya pipe (Daldyno Alakitski area) and garnet from the Mir pipe (Malo-Botuobinski area). Aromatic hydrocarbons with molecular structure of alkilalbocarbons, alkilphenantren and piren predominate.

Hydrocarbon inclusions can be found in minerals of the following parageneses, according to the data of the chemical compound of mineral inclusion: in olivines from magnesium and ilmenite ultramafic magnesium parageneses. Therefore, the environment of crystallization proves to be saturated with reduced hydrocarbon fluids.

Values $\delta^{13}C$ of zircons are similar to values $\delta^{13}C$ of hydrocarbons in olivines from the Udachnaya pipe (Galimov et al., 1988) and in garnets from the Mir pipe (Botkunov et al., 1985). These values take the range of values of isotopes of carbon diamond of eclogitic paragenesis.

Taking into consideration that formation temperature of diamond and its complementary rocks is about 1000°C, P.A.H. are to change into graphite under the given conditions through the reaction:

$$\text{P.A.H.} = \text{C (graphite)} + H_2$$

It is explained through the hydrogen's high concentration. This conclusion conforms to the discovering hydrogen and some other gas inclusions (CH_4, H_2O) in diamonds and in different magmatic minerals.

According to I.I.Kulakova, P.A.H. are formulated under the given condition through the reaction:

$$mCH_2 = \text{P.A.H.} + kH_2$$
$$nCO_2 + mCH_4 = \text{P.A.H.} + kH_2O$$
$$nCO + mH_2 = \text{P.A.H.} + kH_2O$$

Possibly, the source of hydrocarbon for these processes and for the process of diamond formation was the same.

FLUID INCLUSIONS AND QUARTZ TEXTURES IN THE AURIFEROUS VEINS OF LA HIGUERITA MINE, LA LAGUNA AREA, CÓRDOBA, ARGENTINA

GONZÁLEZ, M. Mercedes, and MAS, Graciela R. UNS-CONICET, Universidad Nacional del Sur, Departamento de Geología, San Juan 670, 8000 Bahía Blanca, Argentina. [gonzalez@criba.edu.ar ; gmas@criba.edu.ar]

The FI and textures of auriferous quartz veins of La Laguna area, Córdoba, are studied. The gold bearing veins strike NNW-SSE, related to E-W compression. Quartz veins, set in a narrow brittle-ductile shear zone, cut muscovite schist of the middle Paleozoic Tuclame Formation. Veins are quartz + pyrite, galena and chalcopyrite. Pervasive wallrock alteration produced by infiltration and percolation of fluids consists of sericite, chlorite and epidote.

FI (negative crystals) have variable L:V, and two and three-phase FI coexist. All are essentially H_2O and/or CO_2 with variable salinity, and some have a solid phase (halite). Three types are Type I: one CO_2-rich phase at T(room); cooling results in a separate bubble that homogenizes to L between 4 and 12°C; associated with healed fractures and growth planes; regular shapes; considered pseudosecondary. Type II: two phases at T(room)- L+V, or two immiscible liquids. Subtype IIa: pseudosecondary L+V; associated with type I; on cooling nucleate a low density CO_2 bubble between -35 and -55°C; L:V is about 3:1. Subtype IIb: two immiscible liquids (H_2O+CO_2). Subtype IIc: aqueous L+V, in pseudosecondary planes; vapor around 20%. Type III: three-phase (H_2O+CO_2); primary and pseudosecondary; highly variable phase ratio; groups or trails; $TmCO_2$ suggests small amounts of other volatiles (CH_4 or N_2); $ThCO_2$ to either the liquid or vapor phase suggests trapping of a heterogeneous effervescent fluid.

The Th H_2O+CO_2 is between 250° and 400°C, always to the liquid, with a mean T of about 360°C. Salinity of the aqueous phase, from the T of CO_2 clathrate dissociation, is 7.4 to 12.9 wt% NaCl eq.

Bulk densities range from 0.45 to 0.95 g/cm^3. The spread of densities, besides the initial heterogeneity, may reflect pressure variations during deformation over a fluctuating P-T path, causing selective trapping of CO_2-rich and aqueous ± salt fluid inclusions, mainly in the case of type I inclusions.

1. The wide range of the CO_2-H_2O ratio, between 2:1 and 1:3, even in a single group or trail, suggests the presence of two immiscible fluids during the penecontemporaneous processes of quartz crystallization.

2. According to petrographic and microthermometric evidence fluid pressures in these kinds of veins fluctuated according to the "fault-valve-cycle" (Sibson et al., 1988, Geology, 16:551-555), documented by the varying densities of the aqueous and carbonic inclusions.

3. The maximum densities determined should correspond to fluids trapped during the early and higher P-T phase. On the other hand, homogenization temperatures substantially higher than the main peak of the histogram may be the result of the shear zone reactivation.

4. The PVTX conditions and textural assemblages suggest that these fluids were immiscible during some period of trapping, though the effervescence features are not generalized.

5. Microthermometric analyses of the inclusions reveal a CO_2 rich fluid, with highly variable density and variable H_2O. Furthermore, the distinct fluid inclusion compositions indicate that these CO_2 rich fluids (CO_2>>H_2O) represent an unrecognized category of ore forming fluids.

6. Fluid inclusions from these gold quartz veins provide estimates of pressure and temperature of the fluid dynamic process that were active during mineralization, namely, about 360°C and 2 kb.

	T_mCO_2	T_m ice	$T_m$clat.	T_hCO_2	T_hH_2O-CO_2 (to H_2O)	wt% NaCl eq.	bulk density gr/cm^3
Type IIa	-56.6(?)	-10.8	—	-35/-17 (v)	262	14.67	0.85
Type IIb	-57.6/-56.6	—	3.5/7.5	21.3 (l)	332	6.2/18	0.95
Type IIc	—	-5.3/-9.1	—	—	220	8.3/12.9	0.82
Type III	-56.65	-9.12	6./2.4	19-23 (l)	320/370	7.4/12.8	0.45/0.90

FLUID INCLUSION AND STABLE ISOTOPE GEOCHEMISTRY OF A CAMBRIAN TO ORDOVICIAN CARBONATE-HOSTED ZINC DEPOSIT, SOUTHEASTERN YUKON, CANADA

HEIMBACH, James M., and SPENCER, Ronald J. Department of Geology and Geophysics, The University of Calgary.

The study area is located approximately 90 km northeast of Watson Lake, Yukon, in the southeastern portion of the Selwyn Basin. Lower Cambrian to Middle Ordovician platform carbonates are interrupted by volcaniclastics. Texturally, the carbonates are composed of micrite with early cement and coarse grained replacement dolomite. Sulfides include syndepositional, laminated pyrite and coarse-grained replacement sphalerite and pyrite. This study uses fluid inclusion and stable isotope geochemistry to determine sources of carbonates and sulfides.

The $\delta^{13}C$ values of micrite with early cement range from –0.48 to 2.63‰ (PDB), within the ranges of Cambrian to Ordovician limestone reported by Keith and Weber (1964, GCA 28:1787-1816) (KW) and Gao and Land (1991, GCA 55:2911-2920) (GL). The $\delta^{18}O$ values range from –14.10 to -11.01‰ (PDB), depleted by 4‰ with respect to Cambrian to Ordovician limestone reported by KW and GL. The depletion can be explained by meteoric or hydrothermal influences, either depositionally or diagenetically.

Replacement dolomite $\delta^{13}C$ values are from –0.93 to 1.38‰ (PDB) within the ranges of Cambrian to Ordovician limestone reported by KW and GL. The $\delta^{18}O$ values are from –10.82 to –6.39‰. Fluid inclusion homogenization temperatures (Th) are from 150 to 200°C. The dolomite is in equilibrium with a fluid of composition between 7 and 12‰ (SMOW). Dolomite formed at relatively high temperature, from a distinctly different fluid than the calcite.

Laminar pyrite $\delta^{34}S$ values are from –7.34 to 6.33‰ (CDT), depleted by 25 to 35‰ relative to Cambrian seawater (Claypool et al., 1980, Chem. Geol. 28:199-260). Fractionation associated with bacterial sulfate reduction (BSR) explains isotopic shifts up to 50% (Harrison and Thode, 1958, Trans. Faraday Soc. 54:84-92; Kaplan and Rittenberg, 1964, J. General Microbiol. 34:195-212). These values point to low temperature (syndepositional) biogenic sulfate reduction of a Cambrian sulfur reservoir.

Coarse-grained replacement sphalerite and pyrite $\delta^{34}S$ values are from 17.17 to 18.74‰ (CDT), depleted by 15‰ relative to Cambrian seawater. They are derived from a hydrothermal fluid (140 to 150°C sphalerite fluid inclusion Th), so these data can not be explained by BSR. Thermochemical sulfate reduction commonly results in complete conversion of the sulfur reservoir, yielding isotopic shifts of 2 to 3 ‰ (Ohmoto and Rye, 1979, in Barnes, H.L., ed., Geochemistry of hydrothermal ore deposits (2nd edition)). The $\delta^{34}S$ values around 17 ‰ indicate that the sulfur is from a Devonian, Jurassic, or Cretaceous sulfur reservoir.

STUDIES ON THE FILLING OF PORE SPACE IN THE ROTLIEGENDES SEDIMENTARY ROCKS, SW POLAND: FLUID INCLUSIONS, LUMINESCENCE, ISOTOPES

JARMOLOWICZ-SZULC, Katarzyna. Polish Geological Institute, 00-975 Warsaw, ul. Rakowiecka 4.

The Paproc region, located in SW Poland in the western part of the Polish Lowland, represents a gas reservoir in the Rotliegendes and Zechstein rocks (Karnkowski, 1993, Gas and oil reservoirs in Poland, Part 1 - Polish Lowland, AGH, Krakow, in Polish with English summary, 220 pp.).

Research has concerned the following types of cements - carbonate, quartz and sulphate. The rocks come from five deep drillings.

The fillings of pore spaces were studied from the fluid inclusion, luminescence (fluorescence and cold cathode) as well as stable isotopic (oxygen, carbon, sulphur) points of view, aiming at hydrocarbon migration and diagenetic relations (Jarmolowicz-Szulc, 1997, Use of fluid inclusions in the cements of the Paleozoic rocks from the Polish Lowland in search for oil and gas, Archive materials, Polish Geological Institute, Warsaw, in Polish). Both water and hydrocarbon inclusions were found, the second type showing a sort of dull blue fluorescence and being present only in anhydrites. Due to the position of one phase gas inclusions, time constraints may be set on gas migration. HC inclusions homogenize at -104°C which suggests methane with some nitrogen admixture.

Homogenization of two phase water inclusions occurs between 100 and 130°C for anhydrite and 90 and 120°C for carbonates. Fluid salinity varies between 2 and 10 wt% eq. NaCl.

Isotope data for carbonates show the maximum frequency as follows: $\delta^{13}C$ in the interval of -5 to -3 ‰ and $\delta^{18}O$ from -12 to -7 ‰, which suggests an enrichment of the carbonate cement in lighter isotopes. The oxygen data point to temperature generations of carbonate cements - high temperature of 90 to 125°C and low temperature of 45 to 60°C. The higher range has been also pointed out by the two phase fluid inclusions, while the lower by one phase inclusions. Present day bottom values are close to 100°C.

DENSITY DIFFERENCES IN FLUID INCLUSIONS FROM MONO- AND POLY-METAMORPHIC ROCKS IN THE AUSTROALPINE BASEMENT

KAINDL[1], Reinhard, ABART[1], Rainer, HOINKES[1], Georg, and KNOLL[2], Peter. [1]Institute for Mineralogy-Crystallography and Petrology, Karl-Franzens-University, Graz, Austria. [2]Institute for Experimental Physics, Karl-Franzens-University, Graz, Austria.
[reinhard.kaindl@kfunigraz.ac.at]

The Austroalpine Basement (AAB) is a nappe system comprised of mono- and polymetamorphic metasediments, amphibolites, orthogneisses and subordinately marbles, eclogites and migmatites. Fluid inclusions hosted in metamorphic index minerals were observed in the largely monometamorphic Schneeberg Complex (SC) and in the Radenthein Basement (RB). In both areas garnet-micaschists and hornblende shists dominate. The amphibolite facies parageneses are of Cretaceaous age. Only in the basal parts of the SC relics of an older paragenesis are observed.

In the monophase sections of the SC, primary and secondary CO_2-CH_4-N_2 inclusions (X_{CH4}=0.03, X_{N2}=0.02) with variable densities from 0.8 to 1.17 g/cm^3 occur in the quartz matrix. Only in the basal, polymetamorphic sections primary, low salinity H_2O-NaCl inclusions are observed in garnet cores which pertain to the pre-Cretaceous paragenesis. High Th_{H2O} (L+V→L) = 325°-372°C yield low densities (0.6-0.7 g/cm^3). Aqueous inclusions in "young" matrix quartz have higher salinities (>10 eqwt% NaCl) and densities (>0.8 g/cm^3). This reflects differences in P-T conditions during inclusion entrapment in the course of the pre-Cretaceous and Cretaceous events.

Within the monophase shists of the RB garnet and kyanite porphyroblasts as well as matrix quartz contain primary H_2O-CO_2-N_2-NaCl inclusions. Homogenization temperatures of the three-phase inclusions are 23-24°C for inclusions in garnet. For inclusions in kyanite Th_{CO2} varies from 0 to 27°C, and for inclusions in matrix quartz it varies from -30 to +30°C. This suggests that the original fluid densities were best preserved in garnet. Kyanite and quartz were more susceptible to post metamorphic modification. The composition of the CO_2-N_2 vapor phase is relatively constant regardless of host mineral and fluid density. This leads us to conclude that post metamorphic loss of H_2O may be responsible for these density variations.

This work is supported by the Austrian Science Fund, Project Nr. P11583-GEO.

A CHEMICAL MODEL FOR THE DEVONIAN REMOBILIZATION PROCESS IN THE CAMBRIAN VHMS ROSEBERY DEPOSIT, WESTERN TASMANIA: CONSTRAINTS FROM METAL ZONATION AND FLUID INCLUSION STUDIES

KHIN ZAW[1], HUSTON[2], D.L., and LARGE[1], R.R. [1]Centre for Ore Deposit Research, Geology Department, University of Tasmania, Hobart, Tasmania 7001, Australia. [2]Geology and Geophysics, Australian Geological Survey Organisation, Canberra, ACT 2601, Australia.

The Rosebery deposit in western Tasmania is a polymetallic massive sulfide deposit hosted in felsic volcanics of the Cambrian Mt. Read Volcanic belt. The deposit underwent upper greenschist facies regional metamorphism and related deformation during the Devonian Tabberabberan Orogeny, resulting in folding, shearing and faulting (thrusting) of the ore lenses. The south-end of the Rosebery deposit has undergone metasomatic replacement related to a post-orogenic Devonian granite intrusion. The Rosebery area has also been intruded by shallow-level post-orogenic granitoid plutons. The granite does not outcrop at Rosebery but the existence of a shallow granite intrusion below the south-end of the orebody has been interpreted from gravity data. Metasomatic mineral assemblages related to the Devonian granite have been recognized transgressing Cambrian VMHS minerals at the south-end of the Rosebery orebody.

Cambrian VHMS mineralization at Rosebery consists of three primary sulfide–sulfate zones: a lowermost pyrite–chalcopyrite zone, overlain by a sphalerite–galena±pyrite zone, and further overlain by an uppermost massive barite zone. Three major Devonian replacement zones can be distinguished: (1) a magnetite–biotite±chalcopyrite zone, (2) a pyrrhotite–pyrite zone and (3) a tourmaline–quartz±magnetite zone. Other metasomatic minerals such as fluorite, garnet and helvite are also present (Khin Zaw et al., 1997, Canadian Mineralogist, 35:1-25).

Metal zonation studies indicate that zinc occurs dominantly in a blanket-like enrichment zone in the primary sulfide lenses of the Rosebery deposit; silver exhibits a generally similar pattern. Gold is largely concentrated at the top of the ore lenses. In the transgressive pyrrhotite–pyrite replacement zone at the south-end of the Rosebery deposit, zinc is conspicuously depleted but gold concentrations of more than 20 g/t are observed. In contrast, the biotite-, magnetite-, and tourmaline-bearing replacement zones contain low gold grades (generally less than 5.0 g/t Au). Like zinc, silver is also depleted in the replacement zones but a significant amount of copper is present. Copper concentrations as high as 2 % are observed in the biotite–magnetite zone as well as in the pyrrhotite–pyrite zone. This indicates that although zinc and silver were dissolved and removed during the Devonian replacement event, gold and copper were redistributed and recrystallized.

Microthermometry and laser Raman spectroscopy studies of fluid inclusions in minerals from the Devonian replacement zone indicate that the early biotite-magnetite and pyrrhotite-pyrite assemblages formed from the interaction of moderate- to high- temperature (≥330°C), saline (10-25 NaCl equiv. wt %), CO_2-bearing fluid with the original stratiform lead–zinc mineralization. The later stage tourmaline veining and associated replacement assemblages resulted from lower temperature (≤300°C), less saline (≤10 NaCl equiv. wt %) fluid. The high temperature, high salinity and CO_2-bearing metasomatic fluid support the hypothesis of derivation of this fluid from Devonian granite below the Rosebery deposit.

During the Devonian metasomatic event, gold was most likely remobilized and recrystallized as $AuCl_2$–complex because of the high temperature and high salinity of the fluid. Copper also appears to have been recrystallized during the replacement process, and exhibits minor remobilization. In comparison to copper and gold, zinc, lead and silver have been dissolved and removed probably as chloride complexes.

BEHAVIOR OF SYNTHETIC FLUID INCLUSIONS IN THE SYSTEM H_20-NaCl-CO_2-Ag

KRÜGER, Yves, and DIAMOND, Larryn W. Mineralogisch-Petrographisches Institut, Universität Bern, CH-3012 Switzerland.

Synthetic fluid inclusions have become an important experimental tool for the investigation of high P-T properties of aqueous fluids. In attempting to quantify P-V-T-X properties in part of the ternary system H_2O-NaCl-CO_2 we conducted eight syntheses of fluid inclusions from a 6 wt-% NaCl solution and silver oxalate ($Ag_2C_2O_4$) at 500-700°C and 1400-5000 bar. Under all these conditions we expected homogeneous entrapment of fluid inclusions with a bulk composition of 9.69 mol% CO_2 and 1.74 mol% NaCl, corresponding to one of the isopleths investigated in an optical cell by Gehrig (1980, PhD Diss., HochschulVerlag Freiburg), and we expected that Ag would behave as an inert component. However, the inclusions showed significant deviations from the expected behavior.

In all but one experiment, clathrate dissociation temperatures ($CLA \rightarrow LIQ_{AQ} + LIQ_{CO2} + VAP$) vary by up to 1.3°C and total homogenization temperatures ($LIQ + VAP \rightarrow LIQ$) vary by up to 25°C. In most inclusions two daughter crystals are observable: (1) chlorargyrite (AgCl) was identified by irradiating the inclusions with ultraviolet light such that the originally transparent crystals turned black due to a photochemical reaction, and (2) nahcolite ($NaHCO_3$) was identified by its high interference colors under crossed polarizers and by laser Raman spectroscopy. The sample that shows no spread in microthermometric measurements has the expected bulk salinity, but in all other experiments the bulk salinity is variable: the volume fractions and dissolution temperatures of chlorargyrite and nahcolite vary between inclusions in the same samples, and Tm_{CLA} measurements show a strong negative correlation with Th_{TOT}.

Some of the Th_{TOT} measurements agree with the data of Gehrig (1980) but all our Th_{CO2} ($LIQ + VAP \rightarrow VAP$) values are too low and the calculated bulk molar volumes are too high. Even the inclusions that yielded the correct salinity have a molar volume that is 10% higher than that of Gehrig (1980). Rather than invoking optical problems to explain the low Th_{CO2} data, we attribute the observations to "loss" of CO_2 from the vapor phase to nahcolite and to aqueous HCO_3^-. In accord with this idea we detected a distinct Raman peak in the aqueous phase at 1017 cm^{-1} (corresponding to the C–OH stretching vibration; Davis and Oliver, 1972, J. Solution Chem. 1:329-339). The quartz host showed no peak at this position, hence we infer that the aqueous phase indeed has significantly enhanced concentrations of HCO_3^-.

We conclude that Ag can behave as an active component in fluid inclusions synthesized from silver oxalate and chloride solutions. Inclusions synthesized by this method need to be carefully checked for daughter crystals, for correlations in microthermometric data, and for compatible molar volumes, before reliable P-V-T-X data can be derived for the geologically important CO_2-H_2O-NaCl ternary.

FLUID INCLUSION ANALYSIS OF A SHEAR ZONE HOSTED LODE GOLD DEPOSIT, PADDINGTON, WESTERN AUSTRALIA

LEE, Timothy J., and BROWN, Philip E. Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 West Dayton St., Madison, WI 53706. [tleegold@geology.wisc.edu; pbrown@geology.wisc.edu]

Most Archean lode gold deposits lie in secondary faults spatially associated with large, transcrustal shear zones. These transcrustal deformations most likely serve as the main conduits through which hydrothermal, gold-bearing fluids flowed, before spreading out into secondary shears. The Paddington deposit lies directly within the Bardoc-Broad Arrow shear zone, a north-northwest trending transcrustal deformation zone located in the Norseman-Wiluna greenstone belt of the Archean Yilgarn Craton of Western Australia. The deposit is contained within low to middle greenschist facies metamorphosed dolerites (Paddington dolerite) and high Mg tholeiitic basalts (Paddington volcanics). The deposit consists of quartz-carbonate veins and vein sets, containing arsenopyrite, pyrite, galena, chalcopyrite, and pyrrhotite along with clustered crystals of scheelite. The presence of scheelite can be strongly linked to gold mineralization, due to the similar chemical affinities of W and Au. In the Paddington deposit, scheelite is found in association with Fe-bearing carbonates and various sulfides.

Preliminary analyses of fluid inclusions in quartz indicate the existence of at least four main types of inclusions. Primary, low-salinity (<5 wt.% NaCl), high temperature (T_h = 310-380°C) H_2O-CO_2 and variable salinity (from <5 to 20 wt.% NaCl), high temperature (T_h = 250-320°C) H_2O inclusions are both present, generally as isolated inclusions or separate clusters. Secondary low-salinity (<5 wt. %), low-temperature (T_h = 140-200°C) H_2O and secondary CH_4 inclusions are also common. A few probably secondary, low salinity, relatively low temperature (T_h = 200-230°C) H_2O-CO_2 inclusions exist in some samples from the Paddington pits. Scheelite crystals contain saline, high temperature aqueous and (unclear) high temperature H_2O-CO_2 inclusions, with some secondary low temperature aqueous inclusions near grain boundaries. Quartz crystals in proximity to scheelite contain high temperature H_2O-CO_2 (variable mole% CO_2) and variably saline H_2O in "mixed" clusters (i.e. an individual cluster contains both types of inclusions).

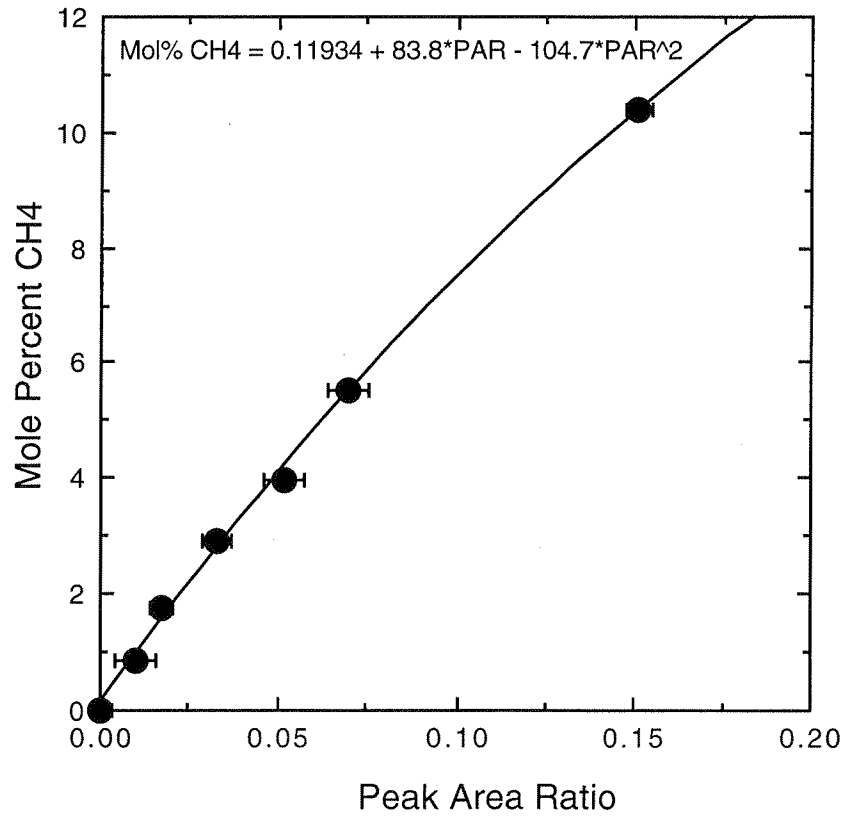
Samples were also taken from less mineralized areas along the Bardoc-Broad Arrow shear. Three main types of inclusions exist in these samples: primary, low salinity, high temperature (T_h = 400-420°C) H_2O-CO_2; secondary, low salinity, low temperature (T_h = 230-270°C) H_2O-CO_2 (lower mole% CO_2 than primary inclusions); and secondary, low salinity, low temperature (T_h = 140-180°C) H_2O. However, these samples lack the variable salinity, high temperature, aqueous inclusions seen in the Paddington pits. Furthermore, samples in hand from these deposits do not contain scheelite or Fe-bearing carbonates.

The presence of H_2O-CO_2 inclusions along the Bardoc-Broad Arrow shear indicates that these fluids most likely originated at some depth and flowed up through this shear. However, gold mineralization only occurs where both H_2O-CO_2 and saline H_2O inclusions occur. Thus gold mineralization may be associated with phase separation (CO_2-rich vs. H_2O-rich fluids), or fluid mixing (deep-sourced CO_2-rich fluids mix with saline, lower temperature aqueous fluids).

QUANTITATIVE ANALYSIS OF SYNTHETIC FLUID INCLUSIONS IN THE H_2O-CH_4 SYSTEM USING RAMAN SPECTROSCOPY

LENG[1], J., SHARMA[1], A., BODNAR[1], R.J., POTTORF[2], R.J., and VITYK[2], M.O. [1]Department of Geological Sciences, Virginia Tech, Blacksburg VA 24061. [2]Exxon Production Research Company, Houston, TX 77252.

Experiments were conducted to test the feasibility of determining the composition of H_2O-CH_4 synthetic fluid inclusions using Raman spectroscopy. Fluid inclusions in quartz were synthesized following techniques described by Bodnar and Sterner (1987). Aluminum carbide plus H_2O served as the source for CH_4. Fluid inclusions were synthesized at 600°C and 3 kbar in hydrothermal cold-seal vessels. Inclusion compositions used to develop the technique had compositions of 0.87, 1.78, 2.93, 3.86, 5.5 and 10.4 mol% CH_4. Homogenization temperatures (Th) for the inclusions were: 0.87 mol% = 307.8° - 308.4°C; 1.78 mol% = 307.9° - 310.7°C; 2.93 mol% = 311.0° - 318.2°C; 3.86 mol% = 316.1° - 320.4°C; 5.5 mol% = 321.4° - 323.7°C; 10.4 mol% = 344.4° - 346.0°C. H_2O-CH_4 fluid inclusions of known composition



were analyzed with a DILOR XY Raman microprobe using the 514 nm line of an Ar^+ laser. The spectral resolution was ±0.3 cm^{-1}. To maximize the signal-to-noise ratio, a collection time of 1024 seconds was selected. All inclusions were analyzed at 350°C in a Chaixmeca heating stage attached to the Raman microprobe. Peak areas for CH_4 and H_2O were obtained by integrating the spectrum using a common base line for both the CH_4 and H_2O peaks. The CH_4 peak area ratio was then calculated for each inclusion analyzed. Figure 1 shows the calculated peak area ratios (PAR) of the H_2O-CH_4 fluid inclusions as a function of the mole fraction of methane. Each of the data points is an average of 10 to 15 individual inclusion analyses. The data show a systematic variation in the peak area ratios determined from Raman spectroscopy and the CH_4 compositions of the inclusions.

FORMATION OF MASSIVE SULFIDE ORES AND BARITE IN THE CENTRAL OKINAWA TROUGH, JAPAN: EVIDENCE FROM STUDIES OF FLUID INCLUSIONS AND STABLE ISOTOPES

LÜDERS[1], V., PRACEJUS[2], B., and HALBACH[2], P. [1]GeoForschungsZentrum Potsdam, PB 4.3 Lagerstättenbildung, D-14407 Potsdam, Germany. [2]FR Rohstoff- und Umweltgeologie, Freie Universität Berlin, D-12249 Berlin, Germany.

Fluid inclusions and sulfur isotopes were studied in massive sulfide and barite samples from active and inactive smokers, mounds, and stockwork mineralization of the hydrothermal "Jade" field in the Central Okinawa Trough (27°15.0'N and 127°04.5'E) which is a tectonically active intracontinental back-arc basin located in the northwestern Pacific. Small faults provide pathways for circulating hydrothermal solutions discharged at the Jade field. Ores forming from these fluids can be chemically characterized by their respective major components: a) Zn-Pb-rich, b) Ba-Zn-Pbrich, c) Zn-Cu-rich, d) Fe-rich replacements, and e) Zn-Pb-rich impregnations of felsic volcanics (rhyolite). Additionally, barite precipitates in the outer edifice of smokers, within soft sediments adjacent to the vents, and in open spaces of the stockwork zone.

The $\delta^{34}S$ values of sulfides from stockwork mineralization and chimneys are very homogeneous but show small variations within their individual sample group. However, sulfides from chimneys always show mean $\delta^{34}S$ values of about 5 ‰, whereas stockwork sulfides are heavier (mean $\delta^{34}S$ ~ 6.8 ‰). The $\delta^{34}S$ values of barites are less homogeneous and vary in the range between 10.2 and 24.6 ‰, indicating mixing of the hydrothermal fluids with ocean water.

Two-phase fluid inclusions in sphalerite from impregnation (stockwork) ores show preliminary homogenization temperatures between 285°C and 347°C (mean 315°C) and yield salinities between 5.0 and 6.5 eq. wt.% NaCl, whereas enargite-hosted fluid inclusions show lower homogenization temperatures of about 270°C and higher salinities (~ 8 eq. wt.% NaCl). The homogenization temperatures of primary two-phase inclusions in barite from the inner fabrics of smokers are considerably lower than those of inclusions in ZnS (mean Th 190°C) but they show salinities similar to those of fluid inclusions in ZnS. Barites from the outer edifice of smokers contain less saline primary fluid inclusions in growth zones (3.7 - 4.5 eq. wt. % NaCl). The homogenization temperatures of these two-phase fluid inclusions are lower than those of primary fluid inclusions in barite from the inner parts of smokers (128 to 189°C). Additionally, all barite samples contain numerous generations of secondary inclusions which mostly are arranged along trails cutting through the crystals. These secondary inclusions are either monophase, i.e. aqueous inclusions, or two-phase, low-salinity aqueous inclusions.

A FLUID INCLUSION STUDY OF GEODES FROM RIO GRANDE DO SUL, BRAZIL: IMPLICATIONS FOR THE ORIGIN OF QUARTZ GEODES

LUETH[1], V.W. and GOODELL[2], P.C. [1]New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 [vwlueth@nmt.edu]. [2]Department of Geological Sciences, University of Texas at El Paso, El Paso, TX 79968. [goodell@utep.geo.edu]

Two types of quartz geodes are recognized from the Parana basalts of the Rio Grande do Sul region of Brazil. Mineralogic, morphologic, and fluid inclusion characteristics differentiate the two types although they are of similar size and shape.

One group of geodes is characterized by dark gray to black exterior chalcedony and with particular chaledony-quartz stratigraphy. The stratigraphy from rim to center consists of: a rim of opal-C, often with a coating of heulandite; transluscent gray chalcedony; flame-shaped milky white chalcedony that grows from the rim area and becomes prevalent toward the center; microcrystalline quartz; drusy quartz. Dark geodes contain pyrolusite and hollandite with variable textures ranging from large euhedral single crystals to acicular sprays and tufts. Fluid inclusion homogenization temperatures are low (less than 40°C) and salinities range between 0.0 and 0.7 equiv. wt. % NaCl.

The other group of geodes is characteristically light-colored. The stratigraphy of these geodes is: opal-C outer layer (with no heulandite); white to yellow chalcedony; white chalcedony (distributed similarly to the dark geodes); microquartz; drusy quartz. Light-colored geodes have more abundant and coarser grained quartz, i.e., chalcedonic material is absent in some samples. Manganese oxide mineralogy is limited to sparse, bladed pyrolusite crystals covered by drusy quartz. Fluid inclusion homogenization temperatures in quartz range from 140° to 175°C with low salinities (0 to 0.7 eq. wt. % NaCl).

Based on the results of our study we infer the two populations of geodes formed as a result of different formation histories. The light-colored geodes may be the result of: 1) a hydrothermal heating event that occurred during or after geode growth or 2) deeper burial that led to a greater degree of silica diagenesis.

INDIVIDUAL FLUID INCLUSION MICROANALYSIS COMBINING PROTON-INDUCED AND PHOTON-INDUCED X-RAY EMISSION (PIXE AND SXRF)

MÉNEZ[1], B., PHILIPPOT[1], P., VANKO[2], D.A., MOSBAH[3], M., CHEVALIER[4], P., DRAKOPOULOS[5], M., POPULUS[4], P., and SNIGIREV[5], A. [1]CNRS, Université Paris 7, Paris. [2]Georgia State University, Atlanta. [3]Lab. Pierre Süe, CEA-CNRS, Saclay. [4]LURE, Orsay. [5]ESRF, Grenoble.

Proton-induced X-ray emission (PIXE) and synchrotron-source X-ray fluorescence (SXRF) microprobes are well-adapted for trace element analysis in individual fluid inclusions. PIXE and SXRF are complementary techniques; they have high spatial resolution and are generally non-destructive. Owing to different ionization cross-sections, PIXE yields more intense X-rays from lighter elements ($Z \leq 22$) whereas SXRF yields more intense heavy-element peaks. Both employ similar computational procedures to obtain concentrations: corrections are required for X-ray self-absorption by the fluid inclusion and absorption by filters (quartz, air, detector window and intentional filters). In addition, PIXE can induce phase changes in inclusions, and beams <20 μm^2 often cause decrepitation.

As a consequence of preliminary experiments, it appears that many aspects of natural samples limit the inclusions suitable for microanalysis. The choice of target inclusion and the careful determination of three-dimensional geometry is essential for reliable analyses. Inclusion depth is the most critical parameter, and because this is poorly determined with optical techniques, the use of an independent means such as the $(K\alpha/K\beta)z$ ratio of an element Z present in solution is essential to minimizing this uncertainty. Furthermore, because the geometry used to estimate element concentrations of fluid inclusions is approximated as a plane-parallel layer of homogeneous material, a spindle-stage study is highly recommended for choosing inclusions with the most adequate morphology.

Strategies for computing the composition vary. Calibration standards like thin-film standards and fluid-filled microcapillaries can be used. The use of external standards requires, however, that experimental conditions remain constant through time, which is generally not the case (e.g., photon intensity fluctuation with time). Alternatively, an internal standard may be used. Approaches that we have tested include choosing one element from previous independent work (e.g., crush-leach), or assuming Cl or total salt concentration is known from microthermometry. The PIXE microprobe, under vacuum, is free of the Ar peak that is ubiquitous in SXRF spectra, so PIXE spectra are more suitable for quantifying Cl. For example, an application to samples from the Brusson gold district (provided by Larryn Diamond) and from a Columbian emerald deposit (provided by Gaston Giuliani) which contain a single generation of inclusions analyzed previously by crush-leach, gave single-inclusion analyses by PIXE and SXRF that are generally very similar to the crush-leach analyses (see Philippot et al., this issue). In another case, freezing runs modeled on the $NaCl-CaCl_2-H_2O$ system for some oceanic fluid inclusions showed that a typical inclusion contained 40 wt.% salts. PIXE analyses of inclusions from the same sample were computed by calculating a Na value by charge balance and adjusting the total salts to 40 wt.%. The results are consistent with previous SXRF experiments.

A FLUID INCLUSION STUDY OF THE FOSTERVILLE MINE, AUSTRALIA: A TURBIDITE-HOSTED GOLD FIELD

MERNAGH, Terrence P. Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601, Australia.

The Fosterville Au mine is located in the world-class, turbidite-hosted Au province in the western Lachlan Fold Belt, Victoria, Australia. The gold field is hosted by the Fosterville Fault zone, a high angle reverse fault system developed on the eastern limb of a complex synclinorium. The mineralized fault breccias are vertical to sub-vertical and ≤35 m wide. Unlike the typical quartz reef Au deposits common in the rest of Victoria, the gold is very fine grained (<50 μm) and is intimately associated with disseminated arsenopyrite and pyrite within pervasively kaolinized and ferruginized lithic breccias in the oxidized zone of the deposit. 1mm to 5cm quartz/carbonate vein stockworks are rare in the oxidized zone but become more common in the sulfide zone at depth. Vein textures vary from crack-seal types to massive extensional veins often with vuggy zones towards the center of the veins. Mineralized quartz porphyry dikes occur within the Fosterville fault zone, containing abundant disseminated sulfides and cut by later quartz/carbonate veins.

Three fluid inclusion (FI) types occur in the quartz/carbonate veins. Type Ia are two-phase liquid-rich FI with <10 vol. % vapor and no detectable CO_2. Type Ib FI are also liquid-rich but contain CO_2 and other gases in the vapor phase. Type II are vapor-rich (>20 vol. % vapor), CO_2-bearing FI and are most abundant. Many Type II FI have only a thin meniscus of water or appear to consist of only CO_2. Type III are three-phase FI containing liquid and vapor CO_2 and these are also very common. FI showing evidence of necking were avoided during further studies.

Raman microprobe analysis of the vapor phase of Type Ib, II and III FI confirms the presence of CO_2, and indicates that N_2 and CH_4 occur in some FI. N_2 in the vapor phase varies from 0 to 18 mol.% and is believed to reflect interaction of the fluids with organic material within the turbidite sequence. CH_4 varies from 0 to 25 mol. % with the highest concentrations occurring proximal to black shales. These results are in accord with measurements which showed CO_2 final melting temperatures between -58.8 and -56.6°C with the most being close to -56.6°C.

Clathrate melting in CO_2-bearing FI occurred around 8.5°C giving salinities of 0.5 to 5.8 eq. wt.% NaCl with a mode at 3.5 wt.% NaCl. Most CO_2-rich FI decrepitated before Th but the remaining FI exhibited a bimodal temperature distribution. The majority homogenize between 234 and 384°C with a mode at 270°C and similar Th are observed for homogenization into both the liquid and vapor, with some FI exhibiting near critical behaviour. However, a small number of Type II FI homogenize between 146 and 198°C. Liquid-rich FI coexisting with Type II FI also homogenize between 133 and 218°C with a mode at 162°C. Their salinities are typically close to 6 eq. wt.% NaCl. Other primary, aqueous FI in growth zones in bladed carbonate crystals homogenize between 212 and 338°C with a mode at 247°C. These FI have much lower salinities (typically less than 1 wt.% NaCl).

Type II fluids containing up to 25 mol.% CO_2 represent the least reacted, deeply sourced fluids that have migrated through the fault zone at Fosterville. These fluids were initially at near critical conditions and were trapped at about 270°C and at pressures from 1.3 to 2.0 kbar. The presence of coexisting aqueous and CO_2-bearing FI which homogenize around 162°C suggest that this fluid undergoes phase separation and cooling possibly resulting from fluid mixing. Other FI in bladed carbonate indicate the ingress of a lower salinity, meteoric? fluid which underwent phase separation at around 247°C. Gold deposition is interpreted to be due to desulfidation reactions caused by phase separation and subsequent fluid mixing. Mineralization within the host rocks occurred as the fluids flowed from the overpressured veins into the host rocks and reacted with more reduced fluids or carbonaceous material to precipitate gold and associated sulfide minerals.

Acknowledgment- I would like to thank Trevor Jackson for his assistance and Perseverance Exploration Pty. Ltd. for permission to publish this work.

THE MINERALOGIC AND FLUID-INCLUSION RECORD OF THE TRANSITION FROM LIQUID- TO VAPOR-DOMINATED CONDITIONS AT THE GEYSERS, CALIFORNIA.

MOORE[1], J.N., ADAMS[1], M.C., and ANDERSON[2], A.J. [1]Energy and Geoscience Institute, Salt Lake City UT 84108 [jmoore@egi.utah.edu] [2]St. Francis Xavier University, Antigonish, Nova Scotia, Canada B2G 2W5.

Studies of vapor-dominated geothermal systems provide a unique glimpse into hydrothermal processes that have not yet been recognized in fossil plutonic environments. The Geysers is the most extensively explored of these vapor-dominated fields and the best characterized. Development of the current thermal system was initiated 1 to 1.5 million years ago during the emplacement of a hypabyssal granitic pluton (Dalyrimple, 1992; Hulen et al., 1997). Petrologic and $^{40}Ar/^{39}Ar$ spectrum dating demonstrate that liquid-dominated conditions persisted in the central Geysers until 0.28 Ma when seismic activity triggered catastrophic boiling and venting (Moore and Gunderson, 1995; Hulen et al., 1997). The system has been vapor-dominated for the last 0.25 million years.

In this paper we describe the conditions associated with the transition from the liquid to a vapor-dominated regime and document the features related to this event. Quartz crystals from three wells drilled in the central and northwestern portion of the field were studied. The crystals contain numerous primary liquid and vapor-rich fluid inclusions, indicating growth in a boiling environment, and solid inclusions of contemporaneous bladed calcite and chlorite. Both the quartz and calcite display evidence of dissolution during mineralization.

Homogenization temperatures of liquid-rich inclusions indicate that mineralization occurred over a temperature range of >305° to 241°C. Although the majority of the primary inclusions yielded salinities near 0.0 weight percent NaCl equivalent, salinities as high as 3.7 were recorded. Temperature-enthalpy relationships indicate that the low salinity waters represent steam condensate whereas the higher salinity fluids are the residual, boiled brine.

Primary vapor-rich inclusions are unusually large, up to approximately 800 microns in length, and typically exhibit negative crystal shapes. Oriented crystals indicate that the primary inclusions developed mainly on growing rhombohedral faces and less commonly on prism faces. Heating and freezing measurements have documented several phase changes. Cooling to approximately -100°C results in the formation of solid CO_2. As the inclusions are warmed, the solid CO_2 sublimes at temperatures that range from -93°C in inclusions from shallow depths to -57°C in deeper samples. Although ice-melting temperatures in most inclusions yielded apparent salinities of 0.0 to 0.4 equivalent weight percent NaCl, inclusions that trapped boiling brine have salinities as high as 2.6 weight percent NaCl equivalent.

The results of this study provide clear evidence of mineralization in a developing vapor-dominated heat pipe. As the heat pipe evolved, slightly acidic condensate formed at the base of the cap rock and drained downward, dissolving quartz, calcite, and other minerals present along the vein walls. Deposition of coarse-grained quartz and bladed calcite occurred when the condensate or mixtures of condensate and brine encountered regions of the fracture zones that were still superheated and boiled. Growth of the quartz was episodic, with periods of rapid growth resulting in the formation of skeletal crystals that trapped large primary vapor-rich inclusions. The formation of late-stage clays, which is commonly associated with this quartz-calcite assemblage, is the result of continued downward percolation of the acid condensate.

TRACING FLUID SOURCES IN AN ACTIVE HYDROTHERMAL SYSTEM: A CASE STUDY OF THE GEYSERS, CALIFORNIA

MOORE[1], J.N., NORMAN[2], D.I., and KENNEDY[3], B.M. [1]Energy and Geoscience Institute, Salt Lake City, UT 84108 [jmoore@egi.utah.edu] [2]New Mexico Tech, Socorro, NM 87801. [3]Lawrence Berkeley National Laboratory, Berkeley, CA 94720.

The Geysers is a large, vapor-dominated hydrothermal system related to plutonic activity beneath the Clear Lake volcanic field of northern California. Although the Geysers hydrothermal system has been vapor-dominated for the last 0.25 million years (Hulen et al, 1997), fluid inclusions trapped in secondary minerals indicate that temperatures within the earlier liquid-dominated regime ranged from 440°C at distances of 282 m from the pluton to 305°C at a distance of about 1700 m. In this paper, we use fluid-inclusion gas compositions to trace the origins of the geothermal fluids and evaluate the processes that have affected them.

The results of this study demonstrate that broad-spectrum gas analyses of fluid inclusions, when combined with their noble-gas compositions, can provide information on the evolution of the hydrothermal fluids that is not readily obtained using other techniques. Veins deposited by magmatic fluids are distinguished by the occurrence of inclusions containing high-temperature halite-saturated brines. These veins are found within 600 m of the intrusive and in the plutonic rocks. Inclusion populations dominated by magmatic waters are characterized by N_2/Ar ratios much greater than air-saturated water (>100) and a He isotopic ratio of approximately 6 Ra. Veins affected by the subsequent incursion of connate or metamorphic waters are also characterized by high N_2/Ar ratios but have a He isotopic ratio of 0.5 Ra and high CH_4 contents. Thus, high N_2/Ar ratios do not in themselves indicate a magmatic influence. N_2/Ar ratios similar to air-saturated water document the still later incursion of meteoric fluids into the plutonic rocks.

Plots of N_2/100-Ar-CH_4/500 demonstrate that there is a striking similarity between the compositions of the modern steam and the fluid-inclusion gases in quartz-calcite veins found in the outer part of the thermal aureole. Steam and inclusion gases from the northwest Geysers have N_2/Ar ratios greater than air-saturated water and high CH_4 contents. These characteristics imply that the fluids are dominantly connate or metamorphic in origin. N_2/Ar ratios and CH_4 contents of inclusions from the southeast and central Geysers show a broad range of values. Early formed inclusions have N_2/Ar ratios similar to those from the northwest Geysers whereas later formed inclusions and the modern steam have N_2/Ar ratios typical of air-saturated water. Samples with high N_2/Ar ratios generally have high CH_4 contents. Thus, these inclusions also record the progressive incursion of meteoric recharge prior to the onset of vapor-dominated conditions. Although the inclusions in these rocks have generally low salinities, and variable N_2/Ar ratios, He isotopic ratios are near 6 Ra and, thus, document the input of a magmatic gas. The presence of a magmatic component raises the possibility that other gases, including H_2S and H_2 also have a magmatic origin.

In part, variations in the compositions of the inclusion fluids can be related to differences in the solubilities of the volatile species during progressive boiling. Evidence of boiling includes the presence of abundant primary and secondary vapor-rich inclusions, variable gas contents, and gas contents that are much higher than could be accounted for by the trapping pressures. Quartz-calcite veins deposited by boiling fluids are characterized by nearly constant CH_4/H_2 ratios on ternary plots of CH_4-CO_2-H_2.

PRELIMINARY FLUID INCLUSION RESULTS FROM THE "EL MUERTO" PEGMATITE, OAXACA, MEXICO

MORALES-ALVARADO[1], Mercedes, and PROL-LEDESMA[2], R.M. [1]Posgrado en Ciencias de la Tierra, UACPyP. [2]Institute of Geofísica, UNAM, Mexico.

The El Muerto pegmatite is located in the Oaxaca metamorphic complex. The Oaxaca complex is the oldest of several crystalline terranes that outcrop in southern Mexico; the peak metamorphic pressure is P = 7.3 ± 1 kb (Ortega, 1986). The complex is granulite facies and consists of granulite, gneiss, charnockite, meta-anorthosite, marble and pegmatites. Zircons from biotite gneiss and syntectonic metamorphic pegmatite in the complex yield U-Pb ages of 1,080 ± 10 Ma (Ortega, 1986). A concordant date of 975 ± 10 Ma for a post-deformational pegmatite gives a minimum age for the last significant deformation stage.

The El Muerto pegmatite is post-deformation, complex, irregular and discordant with the host rock which is an amphibolitic gneiss that consists of hornblende, biotite, microcline, plagioclase, zircon, titanite, chlorite, ilmenite and magnetite. Biotite and feldspar are partially altered to chlorite and sericite, respectively. Five zones can be identified in the pegmatite. They are:

1. Border Zone.- Mainly allanite-plagioclase±muscovite; allanite crystals are subhedral to euhedral in shape. There are minor amounts magnetite, ilmenite, zircon, apatite and titanite.
2. Intermediate Zone I.- Plagioclase-microcline±muscovite±allanite ±magnetite and minor amounts of quartz and biotite.
3. Intermediate Zone II.- Microcline-biotite-quartz±magnetite.
4. Intermediate Zone III.- Microcline-quartz.
5. Core Zone.- Highly fractured massive quartz, milky to transparent. Quartz crystals contain inclusions of allanite, zircon and apatite.

Fluid inclusions occur isolated, along fractures, and forming groups that are not arranged along fracture planes. Microthermometric measurements were performed on isolated inclusions located in areas not affected by fractures. Fluid inclusions are abundant in the quartz crystals, but they are also present in allanite and miclocline.

The fluid inclusions are highly variable in density and composition, ranging from pure CO_2 (gas or liquid or both phases present at room temperature), to CO_2+NaCl (dissolved)+H_2O, CO_2+NaCl (dissolved+halite)+H_2O and NaCl+H_2O (hydrohalite is frequent and some inclusions have daughter minerals). Fluid inclusion composition is inferred from observed phase changes. Homogenization temperatures range from 180° to 300°C. Assuming that the pressure for the Oaxaca complex calculated from geothermobarometers was 7 kb, the maximum trapping temperature would be between 680° and 800°C. Apparent salinity values vary between 20-26 eq. wt.% NaCl in the aqueous phase and 8-10 wt.% in the CO_2+NaCl+H_2O inclusions. Some inclusions decrepitate before reaching homogenization, apparently due to their moderate to high density. There is evidence of immiscible separation of CO_2-rich and H_2O-rich fluids which would occur at a temperature of approximately 350°C.

MAPPING TRACE-METAL (Cu, Zn, As) DISTRIBUTION IN INDIVIDUAL FLUID INCLUSIONS USING A 3RD GENERATION SYNCHROTRON LIGHT SOURCE (ESRF, FRANCE)

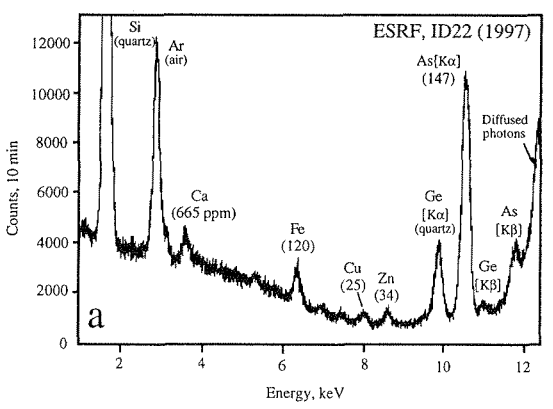
PHILIPPOT[1], P., MÉNEZ[1], B., DRAKOPOULOS[2], M., and SNIGIREV[2], Anatoly. [1]CNRS, Université Paris 7, Paris. [2]European Synchrotron Research Facility, Grenoble.

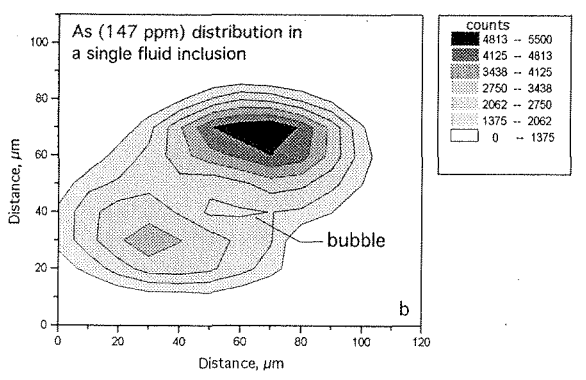
The concentration and spatial distribution of relatively dilute (10 to 100 ppm) trace metals (Cu, Zn and As) were determined in individual fluid inclusions from various ore deposits using synchrotron radiation X-ray fluorescence (SXRF). The analyses were performed on the commissioned beamline ID-22 Micro-FID (Fluorescence, Imaging, Diffraction) of the European Synchrotron Research Facility (ESRF), a third generation synchrotron. The experimental set-up consists of a Fresnel zone plate that ensured focusing of monochromatized X-rays at about 12.5 keV, with a spatial resolution of 2x7 μm^2 and a flux of 10^{10} ph/sec.

The fluid inclusions analyzed here are from mesothermal gold-quartz veins at Brusson, Val d'Ayas, Italian Alps (kindly provided by Larryn Diamond and Bruce Yardley). The presence of only a single compositional type of fluid inclusion that has been the subject of detailed chemical analysis using a variety of bulk (crush-leach) and single-inclusion techniques (microthermometry, Raman spectrometry and secondary ion mass spectrometry) makes these samples ideally suited for testing the potential of the X-ray microprobe to be installed at the ESRF. The inclusions are water-dominated H_2O-CO_2 inclusions with about 5 wt% eq. NaCl.

Fig. 1a shows a typical X-ray spectum obtained during a 10 min acquisition time on a single inclusion (number in parenthesis is the concentration determined by crush-leach; in ppm). Notice that the fluorescence intensity of As is much higher than that of Ca and Fe although its concentration (147 ppm) is lower or similar to the concentration of Ca (665 ppm) and Fe (120 ppm). These differences in X-ray peak intensity are due to three factors. First, X-rays of light elements are significantly or totally absorbed by the quartz host covering the inclusion and the airpath between the detector and the sample. Second, for a given excitation energy (12.5 keV in the present study), the photoionisation cross section scales with Z^4 (Z being the atomic number of the analysed element). Third, since the cross section has a (photon energy)$^{-3}$ dependence, the majority of the fluorescence events arise from photons whose energy is just above the considered absorption edge. In the present case, this implies that the sensitivity is optimized for elements displaying X-ray fluorescence lines close to the excitation energy [As and to a lesser extent Cu (25 ppm) and Zn (34 ppm)]. Fig. 1b shows a contoured map of count rates performed for As in a single fluid inclusion. The area of relatively low count rates towards the center of the inclusion corresponds to the position of the CO_2 vapor bubble.

Although the conditions of analysis were not optimized and will be easily improved using Bragg-Fresnel optics (lower background, higher photon flux and smaller foci), these results indicate that third generation synchrotron light sources can be considered as a promising technique for tracking trace metals in individual inclusions (down to the ppm and possibly tenths of ppm level) and hence, as an invaluable tool for reconstructing the relative chronology of the paleo-hydrothermal events responsible for the concentration of economic resources.





VOLUMETRIC RECONSTRUCTION OF AN OIL INCLUSION USING CONFOCAL SCANNING LASER SPECTROSCOPY

PIRONON[1], Jacques, CANALS[1], Martin, DUBESSY[1], Jean, WALGENWITZ[2], Frédéric, LAPLACE-BUILHE[3], Corinne. [1]CNRS-CREGU, EP 578, BP 23, 54501 Vandœuvre-lès-Nancy, France. [2]ELF AQUITAINE, CSTJF, 64018 Pau Cédex, France. [3]BIO-RAD S.A., 94-96, rue Victor Hugo, BP 220, 94203 IVRY sur SEINE Cédex, France.

Without chemical data about oil trapped in inclusions, the PT conditions of trapping can be directly determined from density or molar volume. Density or molar volume of the oil can be precisely determined by measuring the gas vol.% of the inclusion at a given temperature. Hydrocarbon liquid phases trapped in inclusions are generally clearly observed under UV or visible illumination by fluorescence emission occuring at higher wavelength than the exciting source.

Confocal Scanning Laser Microscopy (CSLM) has been applied to a reference inclusion from MVT deposits and trapped in fluorite, using a MRC 1024 Bio-Rad equipment. Laser light (488 nm) is focused on the sample which is immersed in oil. The fluorescence is collected by the objective lens and imaged onto the confocal aperture in front of a photomultiplier tube. Depth resolutions near 0.5 µm can be achieved, lateral resolution is determined by the laser spot and is about 0.2 µm. Rapid scanning in two dimensions is obtained by the use of two galvanometer driven mirrors. Multiple sections in 2D spaced with constant intervals in depth are collected with a z motorized stage. Three-dimensional images are therefore achieved and computerized in order to measure the inclusion volume. Computer treatment consists of image threshold and contouring (Figure 1). This treatment offered by various programs allows the volume quantification with an accuracy lower than 5%. Surface modelling using GOCAD program has been applied and the 3D reconstruction shows a coherent image of the whole inclusion, however 3D reconstruction of the gas bubble does not fit with an ideal spherical shape.

Gas vol.% determination by CSLM is an important step to use oil inclusions as reliable indicators of physical and chemical conditions of oil migration. Comparisons between Th and gas vol.% data of the inclusions and the thermodynamic properties of reference oils could give us the opportunity to determine a pseudo-composition of the oil in the inclusion. Real trapping temperature and pressure of the oil will be obtained using contemporaneous CH_4-H_2O-NaCl inclusions by intersection of the two isochores (oil and aqueous solution).

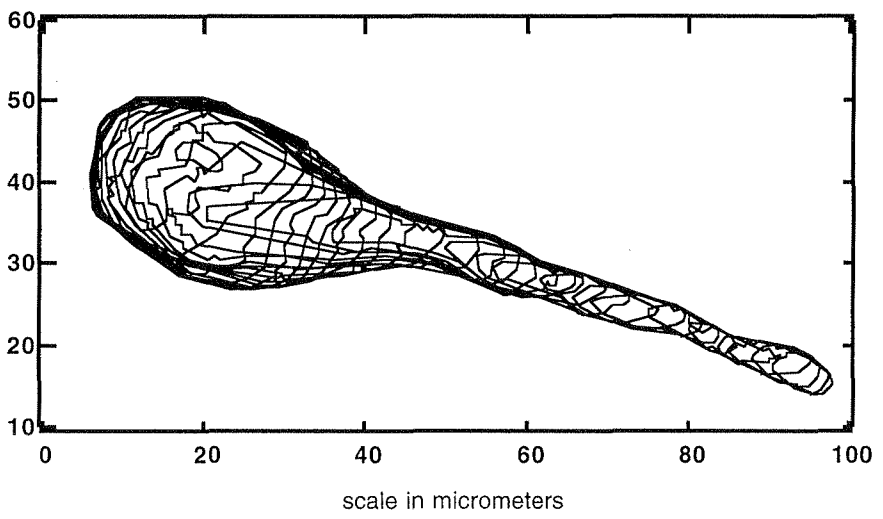


Figure 1: Superposition of CSLM planes for an oil inclusion. Scale in micrometers.

APPLICATIONS OF FLUID INCLUSION TECHNOLOGY TO HYDROCARBON SYSTEMS

POTTORF, Robert J., and VITYK, Maxim O. Exxon Production Research Company, Houston, TX 77252.

The examination of a hydrocarbon system using fluid inclusion technology generally starts with rapid screening of a large number of cuttings samples throughout a well(s). Screening is accomplished by mechanical crushing of rock samples followed by bulk analysis of evolved organic and inorganic fluid inclusion volatiles by quadrupole mass spectrometry. This technology has proven effective for the identification of migration pathways, seal quality, and proximity to reservoired hydrocarbons.

Once zones of interest have been identified, follow-up work using conventional fluid inclusion optical techniques or sophisticated geochemical methods is commonly completed to answer more detailed exploration questions relating to oil versus gas prediction, oil composition and quality through time, and timing of secondary migration. To begin to answer these complex questions, estimates of paleotemperature, paleopressure, and hydrocarbon fluid properties are required. Aqueous fluid inclusions in sedimentary basins accurately record maximum burial temperature, and place valuable constraints on thermal history. In blind tests for both simple and uplifted basins, the fluid inclusion paleotemperature is usually within 10°C of the actual maximum temperature. In rare cases where both aqueous and hydrocarbon inclusions are trapped at the same time, paleopressure along with paleotemperature can be determined. Examples of pressures estimated from fluid inclusions are within 15% of measured data when compared to standard bottom-hole pressure measurements. Either cryomicroscopy or the fluorescence characteristics of individual oil inclusions are used to estimate the oil density or API gravity. This information allows the properties of included oils to be compared with those presently in the trap. The timing of hydrocarbon migration is estimated by combining information on fluid inclusion homogenization temperatures, burial history, and the PVT properties of trapped hydrocarbons. The greatest uncertainty in these estimates is the PVT properties of the hydrocarbon inclusions and is an area for continued research. Biomarker analysis of entrapped hydrocarbons using GC/MS/MS (gas chromatography/mass spectrometry/ mass spectrometry) techniques allows interpretations of thermal maturity and source-oil correlations on extremely small samples. Case studies illustrate concepts, current applications, limitations, and future uses of fluid inclusion technology.

THE COMPOSITION OF GASES IN FLUID INCLUSIONS OF LATE PERMIAN (ZECHSTEIN) EVAPORITES IN NORTHERN GERMANY

PROHL, Hansjörg, and SIEMANN, Michael G. Fachgebiet Mineralogie, Geochemie, Salzlagerstätten; Technische Universität Clausthal, Adolph-Roemer-Str. 2A, 38678; Clausthal-Zellerfeld, Germany. [prohl@immr.tu-clausthal.de; siemann@immr.tu-clausthal.de]

In order to better understand the origin and migration of natural gases in evaporites more than 300 gas bearing inclusions in primary and secondary salts of the North German Zechstein (Late Permian) were analyzed by Laser Raman Spectroscopy. The investigation of secondary samples (Prohl et al., 1997, EUG 9, Strasbourg) was followed by mostly single phase (gas) inclusions of primary origin. The obtained data base about the distribution of gases in the Zechstein Series 2 (Stassfurt) and 3 (Leine) was used to classify three major groups with six further minor groups.

The three major groups are:

1. N_2-CH_4-C_2H_6-H_2-H_2S
2. N_2-O_2
3. N_2-O_2-CH_4

Whereas the group one and two represent a reducing milieu and an oxidising milieu, respectively, the origin of the gases in group three is not settled yet.

The discovery of H_2 in evaporites is of special interest. Hydrogen in fluid inclusions may serve as a natural analogue for hydrogen produced by corrosion due to the possible reaction of brines with the material of the high level waste container in the post-closure phase of a final repository. In contrast to migration experiments on drill cores these investigations on hydrogen bearing fluid inclusions in undisturbed samples enable studies of hydrogen behavior under natural conditions. Two possibilities for the production of H_2 are considered: (i) Development within organic matter due to cracking processes and (ii) radiolysis of hydrogen bearing molecules like H_2O and CH_4 (Prohl et. al., 1997, ECROFI XIV, Nancy).

The confrontation of the compositional groups with the horizons of origin within the Zechstein Series does not deliver a pattern from which conclusions could be made. It is open to further investigation whether the gases (i) were incorporated into evaporite minerals throughout the whole time of evaporation, (ii) represent mobilized components of deeper buried layers (iii) are a mixture of (i) and (ii).

FLUID REGIME AND CONDITIONS OF ORIGIN OF THE SUKHOI LOG (RUSSIA) GOLD-PLATINUM DEPOSIT.

PROKOFYEV[1], V.Yu., DISTLER[2], V.V., SPIRIDONOV[1], A.M., GREBENSCHIKOVA, V.I., YUDOVSKAYA[2], M.A., MATEL[1], N.L., MITROFANOV[3], G.L., and NEMEROV[3], V.K. [1]Vinogradov Institute of Geochemistry, SB RAS, Favorsky str.1a., 664033, Irkutsk, Russia. [2]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, RAS, Staromonetnyi per.35 Zh-17, Moscow, 109017, Russia. [3]East-Siberian Scientific-Research Institute of Geology, Geophysics and Mineral Raw Material, Dekabr'skikh Sobutyi str. 29, Irkutsk, 664007, Russia.

The Sukhoi Log gold (with platinum mineralization) deposit, the largest one in Russia, is located in the Riphean black shale sequences of North Baikal Area. The ore bodies are of stratiform character and are associated with quartz-sericitic and carbonate metasomatites, quartz pockets and veinlets, magnesium and magnesium-iron carbonatites, and pyrite impregnation. Ore mineralization of gold and gold chalcohenides, various in composition, has not been found beyond the altered rocks. The location of platinum mineralization results from above-ore metasomatites, or coincides with the zones of intense gold mineralization (Distler et al., 1996).

Thermal and cryometric investigations of individual fluid inclusions in quartz of different mineral associations provided general physical-chemical parameters of mineralization and geochemical features of the ore-forming fluids.

Impregnated sulfide mineralization formed at 385-205°C and 2375-235 bars from magnesium-sodium chloride solutions with a salt concentration up to 8.5-5.8 wt.% equivalent NaCl. The syngenetic gas fluid is nitrogen of high density (0.53- 0.12 g/cm^3). The ratio of total pressure to the pressure of water (P_{total}/P_{H2O}) is 57.8-7.8. The cross-cutting veinlets with sulfides and calcite formed at 350-275°C and 2280-185 bars from a magnesium-sodium chloride solution with a salt concentration of 10.7-7.6 wt.% equivalent NaCl, with 7.6-1.8 mole/kg of solution CO_2 of 1.1-0.4 mole/kg of solution CH_4. Post-ore veinlets formed at 335-165°C from a magnesium-sodium chloride solution with a salt concentration of 9.5-5.7 wt.% equivalent NaCl.

The features of ore mineralization are associated with a complicated interaction of metal-bearing hydrothermal solutions with organic substance in the black shale sequences. Considerable nitrogen in the gas phase might form from decomposition of high-molecular nitrogen-containing organic compounds of the C_5H_4NS, $C_{12}H_{17}ON$, etc. type, found in the organic substance of ore-hosting black shales (Distler et. al., 1996). The further decomposition of the whole organic substance resulted in the carbonic acid-methane component of the gas phase. The changing redox conditions, pH and Eh led to the decomposition of complexes of dissolved noble metals, and their deposition together with sulfides, which resulted in the formation of the Sukhoi Log deposit.

THE ORIGIN OF THE SHOSHONITE-LATITE ROCK SERIES OF UKSICHAN VOLCANO (KAMCHATKA, RUSSIA), FROM DATA ON MELT INCLUSIONS

PROKOFYEV, V.Yu., PEREPELOV, A.B., and BELOZEROVA, O.Yu. Vinogradov Institute of Geochemistry, RAS, Irkutsk, Russia [vpr@igc.irkutsk.su].

The origin of the shoshonite-latite series in island-arc systems has been so far open to discussion. The mineralogy and geochemistry of rocks of Uksichan volcano (158°15'E-57°20'N) in the Central volcanic belt of Kamchatka, and compositions of their melt inclusions, show that the high-K and subalkalic shoshonite-latite series of the volcanic center is derived from high-K aluminous basaltic magmas and its basement rocks from low-K and high-Mg basaltic melts. Melt inclusions in plagioclases of high-K basalts of the initial, stratovolcanic stage are compositionally proximal to shield volcano shoshonites and latites (Fig.1), but are higher in phosphorus and titanium which accumulate in shoshonitic and latitic magmas until they are involved in later apatite and titanomagnetite crystallization. In other words, glass composition is proximal to that of the residual remaining after fractional crystallization of plagioclase, which attests to the origin of Uksichan rocks from aluminous high-K basaltic melts. Low-K compositions of melt inclusions in the basement basaltoids agree with the general chemistry of the latter, that makes evident the evolutional trend of magma generation from Pliocene to Pleistocene time.

Therefore, the Uksichan shoshonite-latitic rocks derived not from shoshonite basaltic magmas but rather from high-K ones, that are more broadly distributed throughout the island-arc system. The rocks of the volcano were produced by fractional crystallization under gradually decreasing crystallization temperature and growing fluid concentration in the latest differentiates.

Grant of RFBR N 95-05-14358.

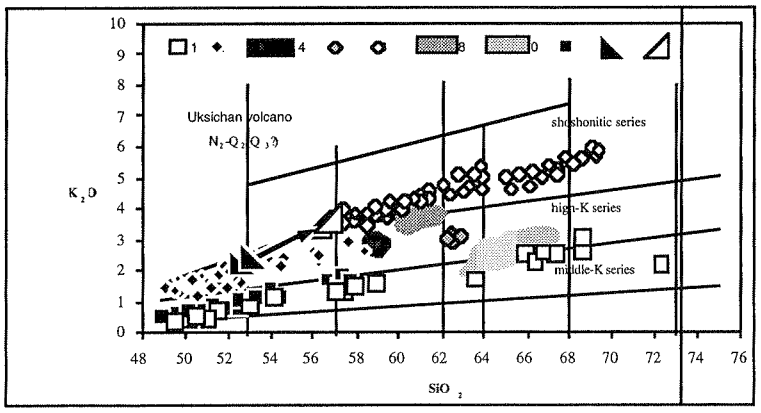


Fig.1. K_2O-SiO_2 variation diagram (wt.%) for rocks in the territory of Uksichan volcano. 1=rocks of volcanogenic basement (N_1^2-N_2); 2=lavas; 3=extrusions of Uksichan strato-volcano; 4=its lavas and ignimbrites (N_2^3-Q_1); 5=lavas and ignimbrites of shield and caldera-type Uksichan volcano (Q_2-Q_3?); 6=high-K andesites and latites of intra-caldera extrusions; 7=high-K dacites of intra-caldera extrusions; 8=lavas of Upper Pleistocene-Holocene shield volcanoes and areal-type cinder cones around Uksichan volcano (Q_3-Q_4); 9=compositions of Uksichan high-K basalts, plagioclases of which contain melt inclusions; 10=compositions of melt inclusions in high-K basalts. Arrow puts together compositions of high-K basalts and melt inclusions.

FLUID INCLUSION EVIDENCE FOR THE INVOLVEMENT OF BASINAL BRINES AND GRANITIC FLUIDS IN THE DEVELOPMENT OF COMPOSITE CORNISH Sn-LODES, SW ENGLAND

RANKIN[1], A.H., CHRISTOULA[2], M., and HALLS[2], C. [1]School of Geological Sciences, Kingston University, Kingston Upon Thames KT1 2EE, UK. [2]Royal School of Mines, Imperial College, London SW7 2BP, UK.

The South Crofty tin mine was the last remaining metal producer in the classic mining district of SW England until its closure in late 1997. Recent studies by Farmer et al. (1991, Mineral. Mag., 55:447-458) have identified two main paragenetic stages associated with cassiterite mineralization in the mine; a tourmaline stage and a later chlorite stage in which fluorite is a common gangue mineral. Published fluid inclusion data on quartz from these two stages of mineralization (Scrivener et al., 1986, Proc. Ussher. Soc., 6:412-416; Farmer et al., op. cit.; Dominy et al., 1996, Trans. Inst. Mining and Metall., 105:B139-143) show homogenization temperature and salinity ranges which are typical of main-stage cassiterite mineralization elsewhere in the orefield (Th = 200-400°C; salinity 2 - 24 equiv. wt.% NaCl). However, the presence of lower temperature, higher salinity fluids which are more typical of "basinal brines" has also been noted.

In this paper we report on the microthermometric and geochemical analysis of fluid inclusions in fluorite from the chlorite stage of mineralisation. We distinguish two separate fluid regimes with similar salinities but quite different origins; a high temperature (HT) and a low temperature (LT) fluid with variable salinities. ICP-AES analysis of leachates shows that the HT fluids are characterized by Na/K atomic ratios of between 3.1 and 9.4 and Na/Li atomic ratios of between 10.6 and 18. These values are significantly lower than the corresponding ratios for LT fluids (Na/K 11.6 to 12.3; Na/Li 52.5 to 77). A similar trend is noted in the Ca/Na ratios inferred from microthermometric measurements. However, the Cl/Br ratios (determined by INAA methods) for the HT fluids (860 to 1333) are much higher than for the LT fluids (303 to 586).

The Cl/Br ratios for the HT fluids are closely comparable with the "magmatic" ratio of between 1124 and 1234 reported by Bohlke and Irwin (1992, GCActa, 56:203-225) for fluids responsible for quartz-tourmaline-topaz (greisen) assemblages in SW England. The alkali ratios are also characteristic of high-temperature granite-associated fluids from the region. By contrast, the alkali and halogen ratios and microthermometric characteristics of the LT fluids are very similar to those for the MVT fluorite deposits elsewhere in the UK where basinal brines are known to have been involved (Christoula, 1992, PhD Thesis, University of London, 262 pp.).

The present result confirms the involvement of basinal brines and "magmatic" fluids in the development of Sn-lodes in SW England, both of which have been modified by fluid-rock interactions and mixing with meteoric fluids. The study also shows the importance of careful paragenetic control when reporting on the geochemical characteristics of composite vein samples, especially from bulk fluid inclusion analysis.

ASCENDING OR DESCENDING WATER FLOW THROUGH YUCCA MOUNTAIN TUFFS? – FLUID INCLUSION EVIDENCE

ROEDDER[1], Edwin, and WHELAN[2], J.F. [1]Dept. Earth and Planetary Sci., Harvard Univ., Cambridge, MA, 02138. [2]U.S.Geological Survey, P.O.Box 25046, Federal Center, Denver, CO, 80225.

The potential site for a high-level nuclear waste repository at Yucca Mountain, Nevada, lies within a thick series of volcanic tuffs, more than 300 meters above the present water table. Recent reports by Technology and Resource Assessment Corporation (TRAC) affiliated scientists (e.g., Hill et al., 1995, Environmental Geology, 26:69-88; Dublyansky et al., 1996, Proceedings of the Pan American Conference on Research on Fluid Inclusions, Madison WI, 38-39) claim that (1) ascending ground water, possibly at elevated temperature, has in the past risen through the thick unsaturated zone and discharged at the surface, and (2) should this recur in the future, it could flood the repository, with serious consequences.

We have studied the fluid inclusions in vein and vug calcite from the tuffs and find that all unsaturated zone calcite contains abundant inclusions that are full of liquid, and lesser numbers of inclusions that are full of gas mixtures of atmosphere-like composition at about one atmosphere pressure. The gas-filled inclusions probably formed by the trapping of exsolved gas bubbles sticking to the crystals as they grew from a film of cool water (probably $\leq 40°C$), infiltrating from the surface and descending through the unsaturated zone. Calcite also occurs well below the watertable, deep in the saturated zone; textural, stable isotope, and fluid inclusion evidence indicates that this calcite formed predominantly during a moderate-temperature hydrothermal event at about 10.4 Ma.

Our fluid inclusion studies of numerous samples from the underground workings of the Exploratory Studies Facility and from Yucca Mountain boreholes have revealed no evidence of either hydrothermal activity or ascending fluids during formation of unsaturated-zone secondary minerals, but have instead confirmed our earlier conclusions that these minerals formed from descending cool waters, above the level of the water table.

FLUID INCLUSION AND STABLE ISOTOPE ANALYSES APPLIED TO MISSISSIPPI VALLEY-TYPE (Pb-Zn) MINERALIZATION ON BATHURST ISLAND, N.W.T., CANADA

ROSE, Scott R.A., and SPENCER, Ronald J. Department of Geology and Geophysics, The University of Calgary.

The discovery in 1995 of a Pb-Zn showing (Harrison and de Freitas, 1996, Current Research 1996-B, Geological Survey of Canada, 81-91) in the lower Blue Fiord Formation (Emsian to Eifelian) on Bathurst Island, N.W.T., rekindled exploration for Arctic Pb-Zn deposits. The new showing occurs in younger rocks than any other eastern Arctic carbonate-hosted Pb-Zn occurrences. The Polaris Pb-Zn orebody, approximately 35 km to the southeast, on Little Cornwallis Island, is hosted by Middle to Late Ordovician shelf carbonates of the Thumb Mountain Formation.

The lower Blue Fiord Formation (BF_1) is the locus for metal sulfides deposited by fluids traveling upwards through a north-south trending fault system. This study addresses the microthermometric and isotopic characteristics of BF_1 within the Pb-Zn showing. Fluid inclusions in replacement dolomite, euhedral dolospar, sphalerite, and late calcispar place constraints on the temperatures of formation and relative salinities of fluids. Carbon and oxygen isotopes of the limestone, dolomitized host rock, dolospar, and late calcispar further characterize the fluids. Sulfur isotopes from sphalerite and galena establish possible sources of sulfate.

The $\delta^{18}O$ values of replacement dolomite are -4 to +3‰ and $\delta^{13}C$ values are -3 to +2‰. Dolospar, which precipitated from hydrothermal fluids (~125°C) migrating upwards along regional faults, is more depleted in $\delta^{18}O$ (-7 to -3‰) and $\delta^{13}C$ (-0.5 to +1‰). Regional dolomitization of BF_1 occurred during early burial, either at low temperatures, or from hydrothermal fluids with the same chemistry as the fluids that formed dolospar.

Sulfide mineralization is confined to a very porous coral/stromatoporoid unit within BF_1, where it lines vugs and fractures. Sphalerite formed at temperatures near 130°C, and post-dates dolomitization. Sphalerite and galena have $\delta^{34}S$ values averaging ~10‰, similar to values from Polaris deposit sulfides.

Late calcispar fills vugs and fractures after mineralization and has a wide range of $\delta^{18}O$ and $\delta^{13}C$ values (-20 to -9‰ and -23 to -1‰, respectively). The calcispar formed from hot (130-160°C) meteoric water and/or seawater. The variation in the chemical and thermal data for the calcite indicates multiple emplacement. The highly negative carbon isotope values point to the influence of organic matter as a source of carbon for the calcispar.

Fluid inclusions, stable isotopes, and petrography indicate the mineralizing fluids of the showing and Polaris were derived from the same source traveling upwards through the N-S trending regional faults.

THE SYSTEM H_2O-NaCl-CO_2 AT ELEVATED TEMPERATURES, PRESSURES, AND SALINITIES: SOLVI, LINES OF EQUAL HOMOGENIZATION TEMPERATURE, AND CRITICAL POINTS

SCHMIDT[1], Christian, and BODNAR[2], Robert J. [1]GeoForschungsZentrum Potsdam, Albert-Einstein-Strasse (Telegrafenberg), 14473 Potsdam, Germany. [2]Fluids Research Laboratory, Department of Geological Sciences, Virginia Tech, Blacksburg, VA 24061, USA. [hokie@gfz-potsdam.de; bubbles@vt.edu]

The interpretation of naturally occurring H_2O-NaCl-CO_2 fluid inclusions usually requires the availability of volumetric and phase equilibrium data over a large range of PTX conditions. However, little is known about isochore locations at salinities above about 10 wt% NaCl and the critical points in this ternary system. In this study, solvi and lines of equal homogenization temperature in the system H_2O-NaCl-CO_2 were determined experimentally for pressures between about 1 to 6 kbar, temperatures of 300° to 800°C, and fluid compositions up to 40 wt% NaCl and 20 mol% CO_2, both relative to water. Critical temperatures were determined for ternary compositions up to 20 wt% NaCl and up to 20 mol% CO_2 relative to water. The dataset was obtained by using the synthetic fluid inclusion technique in conjunction with conventional microthermometry and a hydrothermal diamond-anvil cell.

At constant salinity, the high-pressure portion of the solvus shows a very significant shift to higher pressures and temperatures with increasing CO_2 concentration. For a constant homogenization temperature, the dP/dT slopes of the lines of equal homogenization temperature become steeper (higher) along pseudobinaries with addition of carbon dioxide and particularly with the addition of NaCl. Up to concentrations of 20 wt% NaCl and 20 mol% CO_2, a sharp rise in the critical temperature was observed with increasing salinity at a fixed H_2O/CO_2 ratio. Addition of carbon dioxide causes rapid migration of the critical point towards higher pressures. With increasing $X(CO_2)$, experimentally determined P-T locations of solvi, lines of constant homogenization temperature/isochores, and critical points (Gehrig, 1980; this study) can deviate significantly from those calculated using the equation of Duan et al. (1995) (see Figure).

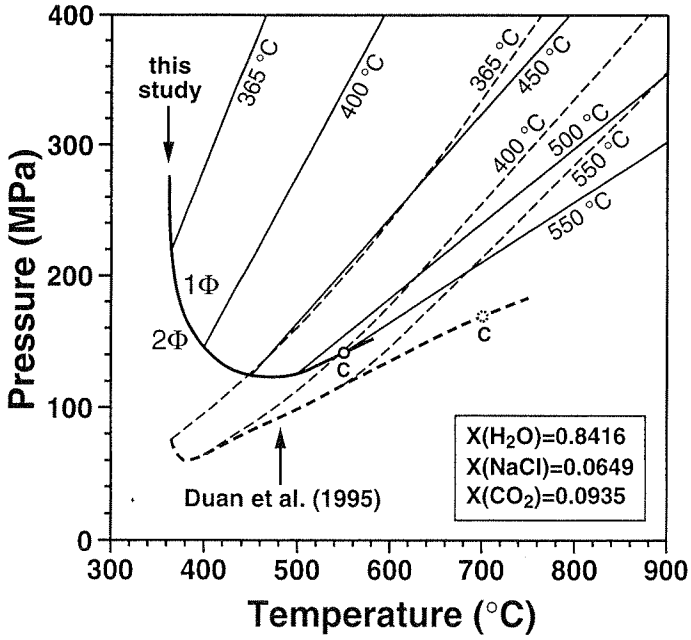


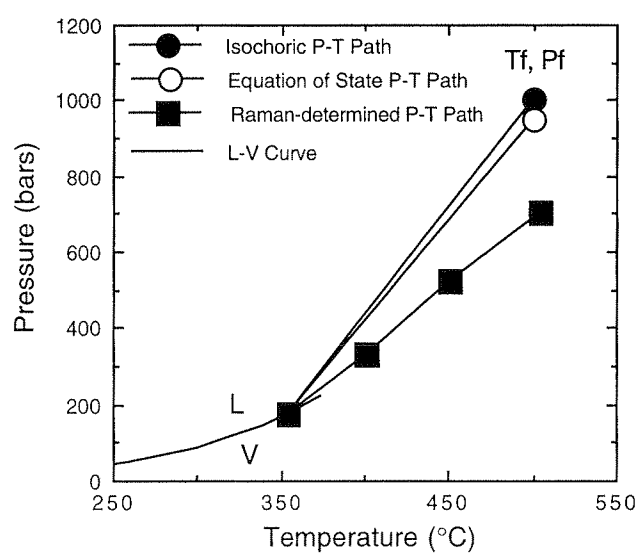
Fig.: High-pressure portion of the solvus and lines of equal homogenization temperature for a constant composition in the system H_2O-NaCl-CO_2 (20 wt% NaCl and 10 mol% CO_2, both relative to water). Thick lines - solvus, thin lines - lines of equal homogenization temperature in the one-phase field, labeled with the corresponding homogenization temperature, solid lines - from fit of experimental data obtained in this study, dashed lines - calculated from equation of state of Duan et al. (1995), 1Φ - one-phase field, 2Φ - coexisting liquid and vapor, C - critical point.

IS THE ASSUMPTION OF ISOCHORIC FLUID INCLUSION BEHAVIOR VALID? A RAMAN SPECTROSCOPIC STUDY OF P-T PATHS OF H_2O FLUID INCLUSIONS

SHARMA, A., LENG, J., and BODNAR, R.J. Fluids Research Laboratory, Virginia Tech, Blacksburg VA 24061.

One of the basic assumptions of fluid inclusion research is that inclusions represent an isochoric system. Following this assumption, it is possible to approximate the formation temperature and pressure of a fluid inclusion by extrapolating the isochore from the P-T conditions at homogenization to some known P or T to determine the P-T trapping conditions. It is also well known that fluid inclusions are not truly isochoric systems, because the volume of the inclusion changes as a result of thermal expansion and compressibility during heating from homogenization to higher temperatures. The magnitude of this elastic volume change is small, and the error that results from ignoring this change is small compared to errors associated with incompletely known fluid compositions and slopes of isochores. However, the assumption that the only elastic volume changes experienced by fluid inclusions during heating are those predicted by the equation of state for the host phase, has not been tested. This is because previously there was no procedure for directly measuring pressures inside fluid inclusions as they are heated through the one-phase field.

In this study the internal pressures of pure H_2O fluid inclusions were determined along their P-T paths based on the shift in the Raman peak for water as a function of pressure. For these experiments, synthetic pure H_2O fluid inclusions in quartz formed at 500°C and 1 kbar were used. Heating experiments were conducted using a Chaixmeca heating stage mounted on the Raman spectrometer. The inclusions homogenized at 353°–355°C and were slowly heated to their temperature of formation (Tf = 500°C). This resulted in the decrepitation of some larger fluid inclusions; however, numerous smaller inclusions were preserved. Homogenization temperatures of those inclusions that did not decrepitate were again determined and only the inclusions showing unchanged Th were used in this study. Those fluid inclusions which showed no change in Th after being heated to 500°C were then heated again and the position of the water peak in the vicinity of 3500 cm^{-1} was recorded using a DILOR XY Raman microprobe. The frequency of the maximum intensity for the water peak was used to determine the internal pressure in the inclusion at that temperature using the previously determined calibration of Frantz et al. (1993). The P-T path predicted by the Raman spectra was compared with the isochoric and with the non-isochoric path calculated assuming the only volume changes are those associated with thermal expansion and compressibility of quartz (Figure). Surprisingly, the P-T path determined by this procedure indicates that the deviation of the P-T path from an isochoric path is significantly more than that predicted by the equation of state for the host quartz. Implications of these results for determining the P-T formation conditions of natural fluid inclusions will be discussed.



MINERAL PARAGENESIS AND PRESSURE AND TEMPERATURE CONSTRAINTS DURING GOLD MINERALIZATION AT THE TURQUOISE RIDGE CARLIN-TYPE GOLD DEPOSIT, NEVADA

SHIGEHIRO, Michiko, and CLINE, Jean S. University of Nevada, Las Vegas, 4505 Maryland Parkway, Box 454010, Las Vegas, Nevada, 89154-4010.

We are investigating ore-stage mineral assemblages and related fluid inclusions at the Turquoise Ridge deposit, a Carlin-type gold deposit located in northern Nevada. Our research addresses three questions: (1) What is the ore mineral paragenesis? (2) At what pressure and temperature did the deposit form? (3) What are the sources of the ore fluids?

The Turquoise Ridge deposit is a recently discovered, deep, high-grade deposit, that is now being developed; ore has been documented to depths of greater than 670 m below the present surface. Ore is hosted by two types of variably metamorphosed sedimentary rocks; brown hornfels hosts ore at shallow levels and black hornfels hosts ore at deeper levels. Ore-bearing brown hornfels is clay-rich and exhibits alternating bands of clay minerals and protolith. Black hornfels is not banded and is a more competent graphitic rock. Gold is present in both host rocks as sub-micron inclusions in ore-stage pyrite.

Twenty-two samples from drill hole 94-172 were selected for detailed paragenetic and fluid inclusion studies. Three populations of pyrite have been identified. Non-ore samples contain (1) pyrite that exhibits coarse, subhedral to euhedral crystals. This pyrite is present in pre gold-ore quartz veins, and the assemblage is associated with a granodiorite stock. Type 2 pyrite occurs as bands of grains, which preserve a sense of bedding, suggesting that this pyrite is diagenetic in origin. Type 3 pyrite is present in high-grade samples, and occurs as fine-grained and framboidal pyrite. Preliminary electron microprobe studies of type 3 pyrite show that these grains are rich in trace metals, particularly arsenic, and contain gold. This gold-bearing pyrite is consistently present both within jasperoid quartz grains, and concentrated along jasperoid quartz grain boundaries. These observations suggest that gold mineralization precipitated prior to, and continued during, jasperoid quartz deposition. Petrographic studies suggest a successive depositional sequence of (1) pyrite with gold, (2) jasperoid quartz, (3) orpiment, (4) realgar, and (5) calcite.

Fluid inclusions in pre gold-ore quartz are approximately 5 micrometers in diameter. Most inclusions are two-phase and contain liquid and vapor. However, vapor-rich and vapor only inclusions are also present. Daughter crystals, possibly calcite, are also present in rare liquid-rich inclusions. Sparse liquid-vapor inclusions were trapped along quartz growth zones, indicating that they have a primary origin; some inclusions occur along planes indicating that they have a secondary origin. Inclusions in jasperoid are small, usually less than 2.5 micrometers in diameter, and are liquid-rich and contain liquid and vapor. Fluid inclusions are sparse in orpiment and realgar, and are generally less than 2.5 micrometers. Other than the few inclusions in growth zones or healed fractures in pre-ore quartz, inclusion origins are unknown. Microthermometric data will be collected from samples from shallow and deep non-mineralized and mineralized samples to determine fluid composition and minimum temperature and pressure of the system. The results of this research will be incorporated into a genetic model for the Carlin-type gold systems.

INVESTIGATIONS ON FLUID INCLUSIONS FROM LATE PERMIAN (ZECHSTEIN) EVAPORITES IN NORTHERN GERMANY

SIEMANN, Michael G., KLINGENBERG, Imke, and PROHL, Hansjörg. Fachgebiet Mineralogie, Geochemie, Salzlagerstätten, Technische Universität Clausthal, Adolph-Roemer-Str. 2A, 38678 Clausthal-Zellerfeld, Germany. [siemann@immr.tu-clausthal.de]

Several fluid inclusions in late Permian evaporates from a salt dome in Northern Germany were investigated to obtain information about the evolution of fluid components in salt rocks. The samples are from drill cores of mostly secondary salts.

The gaseous components in the inclusions were measured by Laser Raman Spectroscopy. The brines were then extracted using a micro drilling system, diluted and analysed by Ion Chromatography. Due to the existence of daughter crystals in the majority of the inclusions different methods were tested to discover the temperature of trapping. Homogenization temperatures obtained by heating-cooling stage are compared with temperatures calculated from distribution coefficients between daughter crystal and brine.

For the interpretation of brine in fluid inclusions, their chemical compositions have to be compared with known solid-solution equilibrium data. This comparison yields information on the quality of extraction and dilution. The data can be presented in a trigonal prism with Mg-SO_4-2K as the base triangle and 2Na or H_2O as the third dimension. Whereas the use of 2Na as the third dimension can give information about the incorporation of halite (NaCl) upon extraction, using H_2O can indicate dilution errors. Due to the existence of different data bases the interpretation of brines in inclusions may sometimes be equivocal. The differences of some of these data bases are shown graphically with special consideration of the stability field of carnallite.

This stability field is of special interest for the investigations because most of the extracted brines are saturated with carnallite. Whereas some brines are free of $MgSO_4$ and are thus only saturated with halite, carnallite and ± anhydrite, other brines are also saturated with kieserite and/or kainite.

FLUID REGIME IN LODE-GOLD DEPOSITS OF THE PROTEROZOIC SERIDÓ BELT, BORBOREMA PROVINCE, NE BRAZIL

SILVA[1], Wanilson Luiz, XAVIER[2], Roberto Perez, and LEGRAND[3], Jean Michel. [1]Instituto de Geociências e Ciências Exatas/UNESP, Rio Claro – SP, Brazil. [2]Instituto de Geociências/UNICAMP, Campinas – SP, Brazil. [3]Departamento de Geologia/UFRN, Natal – RN, Brazil.

The Seridó Belt, Borborema Province, NE Brazil, consists mainly of a Neoproterozoic supracrustal sequence of mica schists, quartzites, metaconglomerates, gneisses, marbles, calc-silicate rocks and amphibolites which overlie a Paleoproterozoic/Archaean gneiss-migmatite basement. During the Brazilian/Pan-African event (~600 Ma), metamorphism to mid-upper amphibolite facies, and the emplacement of numerous granites and pegmatites, mobilized and/or generated fluids which altered the regional metamorphic assemblage in this belt and formed high grade, low tonnage lode-gold deposits along NE-striking, regional-scale transcurrent shear zones. The São Francisco and the São Fernando-Caicó are among the most important of such deposits. The São Francisco deposit is associated with base metal sulfide-pyrite-quartz veins, parallel to oblique to the mylonitic foliation, hosted by garnet-sillimanite-muscovite-biotite schists. At the São Fernando-Caicó deposit, the gold mineralization is hosted by muscovite-biotite schists and sheared metatonalites and occurs closely related to foliation-parallel quartz veins, some with disseminated garnet or garnet aggregates concentrated along their borders. Native gold occurs as free grains disseminated in the quartz veins, as well as associated with pyrite + pyrrhotite + galena + chalcopyrite (São Francisco) or pyrite + arsenopyrite + Fe-Ti oxides (São Fernando-Caicó).

Fluid inclusion studies by microthermometry and Laser Raman microspectroscopy (LRM) in auriferous vein quartz in both deposits identified three FI types: (type 1) low-salinity (3-5 wt% eq. NaCl) H_2O-CO_2; (type 2) CO_2-rich; (type 3) H_2O with varying salinity and solutes. The types 1, 2 and 3 coexist in isolated groups and texturally appear to be primary. In these groups, the $TmCO_2$ for types 1 and 2 inclusions are –56.6°C to –59.0°C, and LRM reveals the presence of N_2 (up to 8.6 mol%) and CH_4 (up to 2.4 mol%). These FI also show a large variation in the density of the carbonic phase, as indicated by $ThCO_2$ (l) ranging from –38°C to 31°C. The type 3 FI in these groups are typically low salinity (Tfice up to –8°C) and dominated by NaCl. Types 2 and 3 FI also commonly delineate intra- and intergranular microfractures, probably representing later fluid phases than those preserved in the isolated groups. Minor H_2O-CO_2 FI (type 1) also occur along microfractures. Microfractures rarely host more than one FI type. The composition of type 2 FI along microfractures are similar to those in the isolated groups, although $ThCO_2$ (l) tends to be higher (10°C to 31°C), particularly for those along intergranular microfractures. Type 3 FI along microfractures in auriferous quartz veins hosted by muscovite schists in both deposits show: (i) São Francisco – Te of –75°C and Tfice between –57°C and –20°C; and (ii) São Fernando-Caicó – Te of –69°C to -36°C and Tfice between –31°C and –8°C. These aqueous fluids have variable salinity and a complex mixture of chlorides of Na, K, Ca, Mg, and Li. In contrast, FI in gold-bearing veins hosted by sheared metatonalites are low salinity (< 4 wt% eq. NaCl) and contain NaCl as the major solute.

The FI study, with structural, petrographic and metamorphic work, shows that $H_2O \pm CO_2$ fluids occurred coevally during at least part of the peak metamorphism and lode-gold deposition. Later, the fluid regime became dominantly aqueous, with compositions dependent upon the rocks with which these fluids interacted during the metamorphism. At the São Francisco deposit, aqueous fluids with complex solutes (Na, K, Ca, Mg, K, and Li) and higher salinity seem related to gold-bearing veins hosted by schists with muscovite and sillimanite confined to shear zones, compared to fluids in barren veins of the biotite-garnet (±andalusite-cordierite) schists. Although we highlight the low–salinity H_2O-CO_2 fluids, it is also likely that multicomponent aqueous brines also played a role in the transport/deposition of the gold and base metals. Although further studies are necessary, loss of H_2S during immiscibility, mixing, or cooling may have occurred.

FORMATION OF MAGNETITE-SCHEELITE SKARN MINERALIZATION AT KARA, NORTHWESTERN TASMANIA: CONSTRAINTS FROM MINERAL PARAGENESIS, FLUID INCLUSION AND OXYGEN ISOTOPE STUDIES

SINGOYI[1,2], Blackwell, and KHIN ZAW[1]. [1]CODES SRC, University of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001. [2]Present Address: Geological Survey Department, Box 50135, Lusaka, Zambia.

The Kara magnetite-scheelite deposit is located 40 km south of Burnie (41°18'S, 145°48'E) in NW Tasmania. The deposit consists of multiple orebodies and the total mineable reserves include 1.7 mt magnetite @ >30% Fe and 0.3 mt scheelite @ 0.52% WO_3. The major orebodies are hosted by the Ordovician Gordon Limestone at the southern end of the Devonian Housetop Granite, adjacent to the granite or separated from it by the Ordovician Moina Sandstone. At least four paragenetic stages of skarn formation and ore deposition have been recognised: Stage I– Garnet-clinopyroxene±wollastonite±quartz, Stage II– Magnetite-vesuvianite±garnet±scheelite±pyrite±chalcopyrite±apatite, Stage III– Epidote-quartz±fluorite±sphene±hematite±pyrite, Stage IV– Amphibole-magnetite-fluorite±calcite±scheelite±epidote±vesuvianite.

Electron microprobe analysis indicates that Stage I garnet is andradite-rich, with low to intermediate levels of grossular and little or no spessartine-almandine-pyrope, whereas Stage II garnet associated with magnetite is about 100% andradite. Stage I garnet has relatively high tin levels, about 0.2% Sn, and appears to be the sole carrier of significant tin in the skarn. Clinopyroxene is diopside-rich. Amphiboles are calcic, mostly hastingsite and magnesian hastingsite. Vesuvianite contains 1.0-1.8% F and low chlorine (0.1-0.4% Cl) while amphibole has 0.7-1.2% F and 0.2-1.0% Cl. Epidote has <.01% F or Cl. The scheelite contains very little molybdenum, typically <2%, compared with 15% in scheelite from the King Island deposit, NW Tasmania (Wesolowski et al., 1986, Econ. Geol. 81:471-477).

Clinopyroxene and garnet in Stage I yielded a Th range of 464.0-585.0°C (mode 525°C). Stage II gave Th of 349.0-578.0°C (mode 500°C) from scheelite and 362.0-571.0°C (mode 500°C) from vesuvianite. Th of quartz from Stage III varies from 326.0-359.0 °C (mode 350°C) and salinities range from 13.0-15.0 eq. wt % NaCl (average 14.0 eq. wt % NaCl). The FI in scheelite, calcite and fluorite from the main scheelite mineralization phase, Stage IV, gave a Th range of 233.0-342.0°C with a mode at 300°C with an average salinity of 11.0 eq. wt % NaCl. Quartz in granite gave Th above 565°C.

Stage II scheelite has $\delta^{18}O$ (SMOW) = 5.6 ‰ (n = 2) while stage IV scheelite has $\delta^{18}O$ = 5.8 ‰ (n = 1). The Stage II and IV magnetite grains (n = 2) have $\delta^{18}O$ = 3.5 ‰ and 4.7 ‰. The $\delta^{18}O$ of ore fluids using the scheelite-H_2O fractionation of Wesolowski et al. (1986, op. cit.) is 9.6 ‰ at 500°C, and 7.2 ‰ at 300°C for the Stage II and IV ore fluids, respectively. The fluid values of 7.2-9.6 ‰ from scheelite compare well with fluid values of 6-10 ‰ for the King Island scheelite deposit (Wesolowski et al., 1986, op. cit.) and 7-10 ‰ for the Glenorchy Au-W-Sb mineralization, New Zealand (Paterson, 1982, Econ. Geol. 77:1672-1687). These $\delta^{18}O$ values are consistent with a magmatic source for the ore fluids.

These mineral paragenetic, fluid inclusion and oxygen isotope studies indicate that magnetite-scheelite mineralization at Kara was formed as a proximal skarn assemblage in carbonate host rocks from magmatic hydrothermal fluids derived from the nearby granitoid source. Skarn formation and ore deposition occurred in stages starting with anhydrous clinopyroxene-garnet metasomatism at relatively high temperatures, >525°C. This early assemblage was partially replaced by the subsequent retrograde deposition of hydrous mineral phases as temperatures declined down to 300°C, but salinities remained at about 10.0 eq. wt. % NaCl. Deposition of magnetite and scheelite occurred in association with hydrous minerals (vesuvianite in Stage II and amphibole in Stage IV). Although the Kara skarn assemblages are predominantly of exoskarn type, the epidote-quartz assemblages developed along the granite margin may be an endoskarn type.

INCLUSIONS IN THE HARNEY PEAK GRANITE AND ITS ASSOCIATED PEGMATITES (BLACK HILLS, SOUTH DAKOTA): IMPLICATIONS ON GEOCHEMICAL EVOLUTION OF MAGMATIC FLUIDS IN A LEUCOGRANITIC SYSTEM

SIRBESCU, Mona-Liza, and NABELEK, Peter. Department of Geological Sciences, University of Missouri, Columbia, MO 65211.

We performed a comparative petrographic and microthermometric study of inclusions within the texturally variable Proterozoic Harney Peak leucogranite (HPG) and in several simple and zoned pegmatites from its associated pegmatite field. Mixed saline CO_2-H_2O (type I) fluids dominate primary and pseudosecondary inclusions in quartz, tourmaline, and garnet of homogeneous, layered granites and pegmatitic segregations within the HPG. Distinct saline aqueous (type II) and carbonic (type III) secondary fluids, which are present throughout all investigated samples, are considered to have formed as a result of unmixing of the type I fluid. The type I primary inclusions from a large, zoned, rare element Bob Ingersoll pegmatite are similar in composition (salinity of aqueous phase around 52 wt% NaCl) and homogenization temperature (ThL-V =300±75°C) to the type I fluids trapped in the HPG. In a narrow simple pegmatite dike, the "Carol Creek" pegmatite, the presence of primary fluid inclusions in large quartz and apatite crystals is questionable as they were largely obliterated by intense circulation of type II and III secondary fluids. Nonetheless, primary fluids are evident in garnet, as well as in small quartz grains within the graphic feldspar quartz intergrowths.

We conducted a preliminary qualitative EDS-SEM investigation of solids within the inclusions to provide insight into the chemistry of fluid populations present at the sampled localities. The EDS-SEM analyses were performed on solid-bearing fluid inclusions and fully crystalline polymineralic inclusions within quartz, tourmaline and garnet. Inclusion geometry and spatial distribution in relation to host crystal zoning indicates that some of the observed solids are daughter minerals crystallized out of a cooling fluid or melt rather than accidentally trapped crystals during host crystal growth or particles mechanically transported by secondary fluids. Mixed H_2O-CO_2 inclusions within Harney Peak Granite and its pegmatites contain various aluminosilicates and simple or complex compounds of P, S, Cl, etc., some bearing rare elements such as Cs, Pb and Sn. In contrast, mixed inclusions in quartz filling necks of boudinaged granite sills, with identical thermometric properties, contain relatively simple Ca, Mg, Na and/or K chlorides. EDS-SEM analysis of daughter crystals proves to be a relatively rapid and simple tool, giving a useful indication of fluid chemistry in situations in which co-existence of distinct populations of fluid inclusions and/or insoluble daughters make bulk chemical analyses of extracted fluid inappropriate. Additional WDS-SEM microanalysis will provide information on elements lighter than Na. This investigation provides a necessary base for more sophisticated in situ microanalyses of fluid and/or solid inclusion chemistry by LA ICP-MS or Raman Spectroscopy.

MANTLE INPUT INTO THE MINERALIZING FLUIDS OF THE COLORADO MINERAL BELT: THE NOBLE GAS STORY

THROWER, C.D., BURNARD, P.G., TURNER, G., and PATTRICK, R.A.D. Earth Sciences Department, University of Manchester, Manchester, England, M13 9PL.

A selection of samples from mineral deposits of the Colorado Mineral Belt have been crushed under vacuum in order to analyze the noble gas isotopic compositions of their inclusion trapped fluids. The noble gas budget of fluid inclusions can come from three primary reservoirs, namely: a) the atmosphere, by way of air saturated ground waters (ASW), b) the crust, and c) the mantle.

The noble gas analyses carried out on these ore deposits clearly shows a very large input of mantle derived ^3He into the mineralizing fluids of the Colorado Mineral Belt. These data fit three different mixing curves, indicating that the ore forming fluids in different deposits are isotopically distinct and the result of mixing between a crustal fluid and three very separate modified magmatic end members (A, B & C).

Distinguishable isotopes are created by the production of radiogenic noble gases in the crust, the retention of primordial ^3He by the mantle and the loss of He from the atmosphere. The isotopic ratios of interest for the atmospheric (ASW) noble gas reservoir include; a $^{40}Ar/^{36}Ar$ value of 295.5 and a $^3He/^4He$ value of 1.39×10^{-6} = the atmospheric $^3He/^4He$ value $\equiv 1R_a$ (all other helium ratios are quoted relative to this value). In comparison, the isotopic ratios of crustal fluids reflect the production of radiogenic elements; $^{40}Ar/^{36}Ar$ value of >295.5 (up to 30,000) and a $^3He/^4He$ value of between 0.01 and $0.05R_a$, while mantle fluids exhibit a $^{40}Ar/^{36}Ar$ value of up to 40,000 and a $^3He/^4He$ value of between $6R_a$ for depleted mantle and $30R_a$ for undepleted mantle. For the Colorado Mineral Belt area the range will be around 6 to 8 R_a.

The study has highlighted the distinct noble gas isotopic signatures and therefore source regions, for the ore forming fluids of the 'Leadville' and 'Sherman'-type mineralization styles, which have been the focus of ongoing debate. These data also suggest a distinct mantle input into the Sunnyside mineralization, a deposit previously regarded as forming from dominantly meteoric fluids.

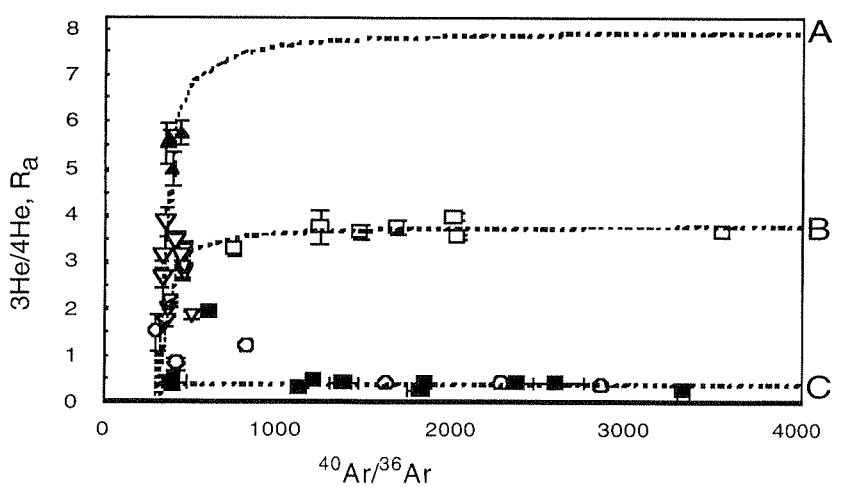


Figure 1: Noble gas analyses for selected deposits of the Colorado Mineral Belt.

(Open square - Columbia; open circle - Sherman; open triangle - Black Cloud; closed triangle - Sunnyside; closed square - London).

Three mixing lines are plotted between a crustal fluid and three magmatic end member fluids (A, B, & C).

ESEM X-RAY EDS: A NEW TECHNIQUE FOR MAJOR ELEMENT CHEMICAL ANALYSIS OF FROZEN FLUID INCLUSIONS USING AN ENVIRONMENTAL SCANNING ELECTRON MICROSCOPE WITH ATTACHED ENERGY DISPERSIVE SYSTEM

TIMOFEEFF, Michael N., LOWENSTEIN, Tim K., and BLACKBURN, William H. Department of Geological Sciences and Environmental Studies, Binghamton University-State University of New York, Binghamton, NY, 13902-6000.

There are several methods to analyze the composition of individual FI. Fluid extraction and chemical analysis by ion chromatography is successful for large FI in halite greater than 200 μm (Lazar and Holland 1988; Horita et al. 1991, 1996). Small FI down to 5 μm can be analyzed by laser ablation-ICPMS (Shepherd and Chenery, 1995; Moissette et al. 1996). Ayora and Fontarnau (1990) and Ayora et al. (1994a,1994b) analyzed small FI using an SEM with an energy dispersive system (EDS) to analyze frozen FI in quartz and halite. We report a new method for analyzing individual FI with an environmental scanning electron microscope (ESEM) and EDS, based on the same principles developed for SEM-EDS analysis.

The ESEM-EDS has advantages over other methods including: 1) direct measurement of major elements in FI, 2) FI in opaque minerals can be analyzed, 3) a conductive coating is not necessary, allowing direct observation of the FI surface to be analyzed, 4) dozens of FI and hundreds of spectra can be analyzed in one session on the ESEM.

Method – Water is removed from the ESEM to eliminate frost buildup on the sample. The chamber is set to hold a dry ambient atmosphere of nitrogen; the ESEM and attached Oxford cryostage are cooled with liquid nitrogen to -150°C. Operating conditions are 1.2 Torr, 20kV beam energy, 1.71 A filament current, and a 50% condenser setting. The "skirt effect", whereby electrons from the beam are scattered by collisions with gas molecules between the emitter/detector and the sample, is minimized by keeping the distance between the last aperture in the electron path and the sample as short as possible, and the environmental chamber pressure low.

Sample preparation – Halite crystals several mm in size are placed in a brass vice. The vice is first filled with hydrated joint compound, which holds the crystal sample and counteracts thermal contraction of the brass when cooled. The sample holder vice is designed to accommodate four droplets of standard aqueous solutions set into small drilled holes and covered with tiny glass cover slips. These provide a smooth flat surface for the liquid droplets when frozen, which ensures proper orientation of the standards to the incoming electron beam and the proper takeoff angle of emitted x-rays. The brass sample holder, with crystal sample and standards, is plunged into a cup of supercooled "slushed" liquid nitrogen. FI in crystals of halite when frozen rapidly in this manner tend to form relatively homogeneous clear "glassy" solids. However, heterogeneous freezing of standards and formation of ice crystals occurs for aqueous standards. Standard solutions with relatively high divalent cation concentrations (Mg and Ca above about 1.5-2.0m) inhibit nucleation of ice crystals and freeze as homogeneous glassy solids (Davis et al. 1990). Standards with low or no divalent cations freeze heterogeneously and form ice crystals. Ethylene glycol (up to 25 wt %) is then added to the standards to inhibit ice formation. Once the samples and standards are frozen, they are transferred to a cold stage attached to the side of the ESEM. A vacuum is pulled on the cold stage to eliminate the chance of frost build-up on the crystal sample and aqueous standards. The crystal sample is cleaved using a manipulator knife to expose frozen FI. The glass cover slips are removed from the frozen aqueous standards with a directed stream of nitrogen gas and the frozen samples are guided into the ESEM for analysis. The process for analyzing the frozen FI on the ESEM starts with the collection of five spectra from each sample. The five spectra are collected in a cross pattern to check the reproducibility of each analysis. Analyses of aqueous standards (brines in the Na-Mg-K-Ca-Cl and Na-Mg-K-SO_4-Cl systems) yield an accuracy (analyzed mean minus expected value over expected value) of 3 percent with the ESEM-EDS technique. Preliminary results from FI in laboratory grown halite crystals give accuracies of 6 percent for elements with atomic numbers greater than magnesium (Ca,K,SO_4,Cl). Analyses for magnesium and sodium in FI in laboratory grown halite crystals are accurate to 18%.

ENVIRONMENTAL SEM (ESEM) X-RAY EDS CHEMICAL ANALYSIS OF FROZEN FLUID INCLUSIONS: PRELIMINARY RESULTS FROM AQUEOUS STANDARDS, FLUID INCLUSIONS IN LABORATORY-GROWN HALITE CRYSTALS, AND PHANEROZOIC HALITES

TIMOFEEFF[1], Michael N., LOWENSTEIN[1], Tim K., BLACKBURN[1], William H., and HARDIE[2], Lawrence A. [1]Dept. Geol. Sci. & Envir. Stud., Binghamton-SUNY, Binghamton, NY, 13902-6000. [2]Dept. Earth & Planet. Sci., Johns Hopkins Univ., Baltimore, MD 21218.

ESEM X-Ray EDS is a new technique developed for analysis of individual FI (see the previous abstract). Aqueous standards in the systems Na-Ca-Mg-K-Cl and Na-Mg-K-Cl-SO_4 are designed to match the compositions of the FI under investigation. Accuracies for the major elements in aqueous standards (mean-expected/expected) are better than 3% and precisions (relative standard deviations) range from 5 to 16%. The ESEM X-Ray EDS technique is not suited for minor and trace element analysis. Quantitative results may be obtained for Ca, Mg, K, SO_4, and Cl at concentrations above about 0.1 wt.%; and 0.5 wt.% for Na.

Halite crystals grown in the laboratory from solutions of known chemical composition (system Na-Mg-Ca-K-Cl) were used to test the ESEM-X-Ray EDS technique: preliminary results give accuracies of 6% to 12% for Mg, Ca, and K.

The ESEM-X-Ray-EDS technique is being used to analyze FI in Phanerozoic halites to address the unresolved question of whether seawater has changed chemical composition over geologic time. Recently, Hardie (1996) suggested that secular changes in the primary mineralogy of potash evaporites, which occur in phase with mineralogical cycles in marine limestones ("aragonite seas" versus "calcite seas"), could be explained by secular changes in the major ion chemistry of seawater. Spencer and Hardie (1990) and Hardie (1996) proposed that small changes in the contribution of mid-ocean ridge hydrothermal waters relative to river waters, the two major sources of ions to the oceans, could produce changes in seawater chemistry, which, in turn, could change the mineralogy of marine evaporites and limestones. Earlier studies of marine halites (Das et al., 1990; Horita et al., 1991, 1996; Land et al. 1995), done by direct extraction followed by chemical analysis via ion chromatography, were limited to large FI (>200 μm) of uncertain origin. Preliminary results from the Permian Salado halite, New Mexico (Drillhole ERDA-9 WIPP-3, depth of 859 m) show that the major element chemical composition of relatively small primary FI (60 μm) along crystal growth bands is the same as the chemistry of the large FI analyzed by Horita et al. (1991). It therefore appears that large FI in halite from primary unrecrystallized halite beds in the Salado Formation contain syndepositional surfaces brines.

FI in crystals of primary halite from geographically separated deposits of the same age are being analyzed in order to obtain a "global" seawater signal. For example, FI in Permian halites from the southwestern U.S., the Central European Basin (Poland, Germany), and the East European Basin (Ukraine, Belarus) will enable distinction between a global seawater signal and an "altered seawater" chemistry modified by factors such as contamination by nonmarine inflow waters and syndepositional recycling. To backtrack from the brine analysis obtained via ESEM X-Ray EDS to the required parent seawater compositions, the water evaporation computer program of Harvie and Weare (1980) is used as a forward modelling tool.

Preliminary results show that Permian evaporites (Salado Formation, New Mexico and Hutchinson salts, Kansas), formed from parent waters close to modern seawater in major element composition, but with somewhat higher Ca and lower SO_4 as reported by Horita et al. (1991). Cretaceous evaporites from the Congo Basin, west Africa, contain sylvite (KCl), the unusual Ca-Mg chloride mineral tachyhydrite, and no $MgSO_4$ salts. FI in crystals of primary halite contain high calcium (m_{Ca} = 2.9 to 3.2), m_{Mg} = 2.8 to 3.5, and m_K = 0.15 to 0.18, all of which indicate a parent water quite different in composition from modern seawater. If FI in halite from other geographically separated deposits of Cretaceous age show similar chemical compositions, then the case may be made that Cretaceous seawater differed from modern seawater.

FE-RICH HYPERSALINE AQUEOUS AND CO_2 INCLUSIONS, ASSOCIATED WITH RETROGRADE METAMORPHISM OF THE CHLORITE-MUSCOVITE-QUARTZ SCHIST FROM THE SOPRON-AREA (EASTERN ALPS, W-HUNGARY)

TÖRÖK, Kálmán. Department of Geophysics, Eötvös L. Univ. H-1082 Budapest Ludovika tér 2., Hungary. e-mail: torokklm@ludens.elte.hu

Secondary aqueous fluid inclusions with soluble daughter mineral(s) and carbon-dioxide inclusions were studied from quartz veins of garnet bearing chlorite-muscovite-quartz schist of the Sopron area (Eastern Alps, W-Hungary). The rock belongs to the Grobgneiss series of the Lower Austroalpine nappe system. Thermobarometry on first generation garnets shows pressures between 1.3 and 1.4 GPa between temperatures of 620° and 640°C. A later generation of garnets gives 0.96 to 1.1 GPa pressure and 556° to 608°C temperature. These P-T estimates are consistent with those obtained for the surrounding orthogneisses (Török, 1997).

All of the fluid inclusions were found in quartz veins, which may contain tourmaline and rutile as well. The inclusions are secondary and occur along healed fractures which cut several grain boundaries. Most of the inclusions contain a supersaturated aqueous fluid with one or more daughter minerals and variable amounts of CO_2.

Several low temperature phase transitions can be observed in the inclusions. During freezing, three new solid phases appear. The first phase appears during cooling between -9° and -30°C and dissolves between +23 and +92°C. The second phase appears during warming at about -85°C and disappears between -58.2° and -47.3°C ($CaCl_2$-hydrate or $FeCl_2$-hydrate?). The third phase forms by reaction of the soluble daughter mineral with water and disappears metastably between +7.8° and +12.5°C (NaCl-hydrate?). First melting of the ice occurs between -56° and -59.4°C and ice melts between -38.1° and -18°C. During heating, the solid phase dissolves between 193.5° and 250.3°C. All of the inclusions decrepitated prior to homogenization, between 265° and 370°C.

Melting of the solid CO_2 phase in the CO_2-bearing inclusions occurred between -56.6° and -58.2°C, which indicates minor N_2 or CH_4. The CO_2-hydrate disappeared between -17.8° and -19.3°C. Homogenization of CO_2 phases occurred between -8.0° and +24.1°C. EDS analyses of precipitated salts showed Fe, Ca, Na with minor Zn, K, and Mn as cations and Cl and SO_4 as anions.

Isochores of CO_2 inclusions show that infiltration of the CO_2-bearing, hypersaline fluids occurred during retrograde metamorphism. The infiltration of the fluids facilitated retrograde metamorphic reactions such as breakdown of staurolite to fine-grained muscovite-paragonite ± albite ± chloritoid and breakdown of biotite to chlorite. Tourmaline precipitation occurred not only in quartz veins, but also in the rock matrix. These features show that the retrograde fluids were not confined to the quartz veins, but they entered into the rock, causing the above changes.

The author acknowledges the financial support received from the ìMagyary Zolt·nî postdoctoral scholarship sponsored by the ìFoundation for the Hungarian Science and Higher Educationî. This work was also supported by OTKA (National Scientific and Research Fund) grant number F0158860 and OTKA postdoc grant number D23918.

PLASTIC FLOW ASSOCIATED WITH REEQUILIBRATION OF FLUID INCLUSIONS IN QUARTZ

VITYK[1]*, Maxim O., BODNAR[1], Robert J., and DOUKHAN[2], Jean-Claude. [1]Department of Geological Sciences, Virginia Tech, Blacksburg, VA USA 24061 [2]Universite Sciences & Technologies de Lille, Lille, France 59655 * Current address: Exxon Research Production Company, PO Box 2189, Houston, TX 77252-2189. e-mail max.o.vityk@exxon.sprint.com

Aqueous synthetic fluid inclusions in quartz were experimentally reequilibrated for 30 and 180 days at conditions of internal overpressure. Microstructures associated with reequilibrated (stretched) fluid inclusions were examined with the TEM. Quartz in healed fractures in samples that were not subjected to overpressures shows low dislocation activity. Quartz adjacent to reequilibrated fluid inclusions, however, showed a marked increase in dislocation activity compared to un-reequilibrated samples. Stretching of the inclusion walls occurred anisotropically by expansion of mobile dislocations in their slip systems. Dislocation expansion was controlled by glide in the rhombohedral planes {1011} restricted to narrow zones (<3 μm) in the immediate vicinity of the fluid inclusion walls outside of the healed fracture plane. These plastic zones were observed after both short term (30 days) and long term (180 days) experiments and can be attributed to hydrolytic weakening of quartz matrix around fluid inclusions due to water diffusion during the experiment. Association of water bubbles with dislocations shows clearly that water was lost from inclusions during both the 30 and 180 day experiments. Our results indicate that even relatively fast experimental loading rates allow synthetic fluid inclusions in natural Brazilian quartz to recover (chemically and volumetrically) such that internal stresses probably never reach the point where the inclusions fail by brittle fracture. The driving force for fluid inclusion recovery arises from two complementary, competing mechanisms: plastic deformation of the inclusions walls weakened by water, and water leakage induced by preexisting and strain induced dislocations.

FRACTURE-CONTROLLED FLOW OF MINERALIZING FLUIDS IN BASEMENT ROCKS BENEATH CARBONATE-HOSTED BASE METAL DEPOSITS, IRELAND

WILKINSON[1], J.J., and EVERETT[2], C.E. [1]T.H. Huxley School of Environment, Earth Science & Engineering, Imperial College, London SW7 2BP, U.K. [2]Department of Geology & Geophysics, Yale University, New Haven, CT 06520, USA. [j.wilkinson@ic.ac.uk]

Ordovician-Silurian rocks, which form the metasedimentary basement to the Zn-Pb-Ag mineralized Carboniferous basins of Ireland, are exposed in a number of inliers throughout the Irish Midlands. In the Silvermines district, these rocks are host to several different cross-cutting vein types which are locally abundant in E-W- and NW-SE-trending fault zones: (1) Early hematitic calcite-quartz ± pyrite; (2) Quartz-calcite ± sphalerite, galena, chalcopyrite, pyrite, barite; (3) Ankerite-ferroan dolomite-quartz ± sphalerite, pyrite. Structural analysis indicates that the veins probably formed due to reactivation of pre-existing faults and their orientations are consistent with formation under a NE-SW dextral transtensional regime, as was developed during the Lower Carboniferous mineralizing event. Primary fluid inclusion data from vein types 2 and 3 show homogenization temperature-salinity characteristics (Th range: 123-238°C, sample means: 144-216°C; 9.7-20.6 wt% NaCl eq.) comparable with the high temperature fluid end-member reported from the overlying base metal deposits. Significantly, primary inclusions hosted by quartz and sphalerite commonly contain CO_2 as has been recently reported in sphalerite-hosted inclusions from the Navan deposit. Bulk fluid inclusion analyses on quartz vein samples show that the fluid composition is comparable with experimental data on seawater equilibrated with greywackes at temperatures of 200-300°C and with contemporary submarine hydrothermal vent fluids. In particular, the very low Mg content and elevated CO_2 are typical of seawater that has interacted extensively with crustal rocks. Alkali geothermometry gives temperatures (158-219°C) not significantly different to mean homogenization temperatures suggesting that the veins at the present level of exposure formed under low fluid pressures, at quite shallow depths. These data provide convincing evidence for the regional flow of high temperature fluids, similar to the ore-forming fluids, within the Lower Paleozoic metasedimentary basement. Furthermore, fluid compositions are consistent with the fluids having equilibrated with basement rocks and are permissive of a seawater origin. In combination with existing isotopic data and thermal constraints, this strongly suggests that deep circulation of surface-derived fluids through fault and fracture zones was a fundamental process in the genesis of the Irish deposits.

PARAGENETIC AND FLUID INCLUSION DATA FROM THE VIZCACHITAS PORPHYRY COPPER PROJECT, CENTRAL CHILE

WILLARD, David T., and CLINE, Jean S., University of Nevada, Las Vegas, NV, 89154.

The Vizcachitas porphyry system, located in the central Andes mountains of Chile, contains primary chalcopyrite (vein and disseminated) and bornite (disseminated) copper mineralization. The system also contains primary vein and disseminated molybdenite mineralization that appears to be related to emplacement of a granodiorite intrusive body.

The paragenetic sequence at Vizcachitas can be constrained through cross cutting relationships that indicate the presence of at least six distinct vein types. The earliest veins (type A) are quartz/biotite/sulfide veins. These veins commonly have pyrite and chalcopyrite at the center of the quartz vein with biotite forming along the outer edge of the vein; however, biotite locally occurs with sulfide minerals in the centers. These veins cut through host rocks in the system that range from diorite to quartz-diorite and from andesite porphyry to andesite/dacite (?) porphyry. Quartz/biotite/sulfide veins have not been observed cross cutting granodiorites. Chlorite/quartz veins (type B) cross cut the quartz/biotite/sulfide veins (type A) and previously mentioned host rocks. Type C veins are chlorite/sulfide veins; these veins cross cut all types of host rock. Type D veins are quartz/molybdenite veins. Molybdenite forms along the outer edges of the vein in granodiorite host rock. Molybdenite is generally found in the center of the quartz veins in other host rocks. Quartz/molybdenite veins cross cut chlorite/sulfide veins in granodiorite. Type E veins are quartz/pyrite/sericite veins; these veins occur in all rock types and cross cut all previously described veins. Type E veins generally contain quartz with pyrite in the center of the vein, and exhibit sericite selvages. The latest set of veins to form are gypsum/anhydrite (type F) veins that cross cut all previously mentioned rock types and veins.

The following populations of fluid inclusions were identified, in decreasing order of abundance. Type 1 inclusions are liquid-rich and contain liquid (L) + vapor (V) ± small opaque daughter crystals (SO). Type 1 inclusions are subdivided into type 1a inclusions that contain L+ V + SO ± small translucent daughter crystals (ST) and type 1b in which only L + V are visible. Vapor bubbles occupy ~30 to 55 volume percent of the inclusion. Type 2 inclusions contain L +V + halite (H) ± SO ± ST. Some inclusions are simple L + V + H inclusions; however several SO and ST daughters are common. Type 3 inclusions contain only L + V with vapor bubbles occupying < 20 volume percent of the inclusion. Type 3 inclusions are liquid-rich and commonly are irregular in form. Type 4 inclusions contain only L + V with vapor bubbles occupying >68.5 volume percent of the inclusion, these homogenize to vapor upon heating.

Preliminary microthermometric data have been obtained for type 1 and 4 inclusions. Type 1a inclusions (most abundant) display two modes of homogenization temperatures (Th), 340°C to 380 °C and 480°C to 500°C. Most type 1a inclusion salinities range from 4 to 5 weight % NaCl equivalent. Type 1b fluid inclusions homogenize from 330°C to 410°C. Salinities for these inclusions range from 4 - 8 weight % NaCl equivalent. Type 4 fluid inclusions homogenize from 420°C to 540°C.

Collection of microthermometric data will continue with the following goals: 1) obtain data for type 2 and 3 fluid inclusions, 2) correlate fluid inclusion data with vein type and associated alteration type, 3) determine minimum pressure and temperature conditions at the time of metal precipitation during the different stages of vein formation, and 4) determine the relative timing of the inclusion populations to identify the evolution of the fluid.

THE GAS COMPOSITION OF INCLUSIONS IN ACCESSORY MINERALS OF BAROFAVOURITE AND HEAVY LEVEL TYPES OF MAGMATIC COMPLEXES OF ROCKS OF THIEN SHAN.

YUSUPOV, Roostam G., POLICKOVSKY, Vladimir S., SAVARDDINOV, Ildar A., and UMAROV, Batir N. Uzcomgeo, 1, Furcat str., Tashkent, 700027, Uzbekistan.

The gas composition of inclusions in accessory barofavourite and heavy level minerals (virgin metals and non-metals on the base of Fe, Si, Cr, etc., siliciums and carbidiums of metal and non-metal etc.) of magmatic complexes of rocks of Tien Shein and nearby territories were studied thermobarogeochemically (TBG) by vacuum decrepitation and gas chromatography. Results are:

NN samples	[1]	A-224	TK-3	K-2	[2]	K-3
Components						
O_2	-	-	5.2	-	-	2.2
H_2	-	2.1	1.4	20.1	19.4	23.7
CO	-	0.1	4.1	4.4	3.8	1.8
CO_2	21.0	28.8	9.2	10.3	15.5	19.4
CH_4	1.5	0.3	0.1	4.2	3.7	2.0
C_2H_4	30.0	-	-	0.5	-	10.5
CH_3OH+ CH_3CH_2OH	-	-	-	-	2.0	-
H_2O	-	27.9	7.4	9.8	39.6	10.0
N_2	47.0	40.9	72.0	50.3	15.9	30.3
Ar	0.8	-	-	0.3	-	0.1

Samples: [1]- aggregate of zyussite, shamrabaevite, graphite; A-224- ferrite ((-Fe); TK-3- aggregate of josephinite, chromite and titanomagnetite; K-2- diamond (Coshmansay diatreme); [2] - diamond (Arkanzas): K-3 - mawsonite.

Oxidized gases (H_2O, CO_2, etc.) increase in the earth's crust as the fugacity of oxygen increases. In Tien Shan, the "K"-oxygen of fluids of melt systems is near 3. This coefficient is near 10 in mantle rocks from old platforms of the earth. Deep fluids are transformed and oxydized during crystallization of magmatic systems in earth's crust.

Summary: 1) formation of deep magmatic centers and having them by gas-fluid components etc. have a propensity to periods of tectonomagmatic activation of Tien Shan territory and compose with whole degassing of mantle substance; 2) carbon components of gas-fluid systems (CO, CH_4, CO_2, etc.) are important in the transportation of metals and non-metals; 3) variation of the coefficient of oxygen of gaseous composition of rocks and minerals ("K"-oxygen from 1 to 10 and more) correlates with the laterally heterogeneous composition of gas-fluid systems; 4) virgin Ag, Cu, Te, Sb, etc. hydrothermal - ore deposits, from the composition of hydro-gas inclusions and from the value of "K"-oxygen, have no contact with deep processes.

THE EVOLUTION OF PRESSURE, TEMPERATURE AND COMPOSITION OF HYDROTHERMAL FLUIDS IN A REGIONAL SHEAR ZONE DURING RETROGRADE METAMORPHISM, REGIONAL UPLIFT, AND COOLING: THE KASPERSKE HORY GOLD DEPOSIT CASE STUDY (BOHEMIAN MASSIF, CZECH REPUBLIC)

ZAK[1], Karel, DURISOVA[1], Jana, STRNAD[2], Ladislav, GOLIAS[2], Viktor, LEACH[3], David, SNEE[3], Lawrence W., VIETS[3], John, and STEIN[4], Holly J. [1]Czech Geological Survey, Klarov 3, 118 21 Prague, Czech Republic. [2]Charles University, Albertov 6, 128 43 Prague, Czech Republic. [3]U.S. Geological Survey, P.O. Box 25046, Denver, CO 80225, USA. [4]AIRIE Partnership, Colorado State University, Fort Collins, CO 80523-1482, USA.

Gravitational collapse of overthickened orogenic crust is typically accompanied by extensional stresses. Collapse-related extensional structures mostly include high-angle brittle and low-angle ductile normal faults. During retrograde metamorphism and uplift of metamorphic core complexes, episodes of crustal fluid movement usually occur in regional fault and shear zones. These fluids of highly variable composition can circulate through a shear zone in episodes separated by millions years. The Kasperske Hory gold deposit is located in a regional shear zone in the high-grade metamorphosed Moldanubian Unit (core unit of eastern part of European Hercynides) in the southern part of the Bohemian Massif of the Czech Republic. Hydrothermal mineralization occurred here during several successive stages of fluid movement during Hercynian retrograde metamorphism, uplift and cooling.

Stage 1 mineralization is represented by several structural types of quartz veins that developed within the shear zone during extensional-shear deformation under ductile/brittle transition conditions. Some types of veins that formed during stage 1 mineralization contain abundant oligoclase and muscovite. Oxygen isotope thermometry (muscovite-quartz and oligoclase-quartz) reveal temperatures in the range 640-580°C and 680-460°C, respectively. These are similar to temperatures derived from arsenopyrite thermometry. Calculated H and O isotope compositions for the fluids ($\delta^{18}O$ +10.5 to +11.0 ‰; δD -40 to -50 ‰) indicate that the fluids were in equilibrium with rocks of the host metamorphic sequence. The $^{39}Ar/^{40}Ar$ data for vein muscovites of stage 1 range between 331 and 325 Ma and do not represent the time of vein formation but rather a cooling age (<~330 °C) of the hydrothermal system. Stage 2 is characterized by the presence of abundant Co+Ni sulfoarsenide with composition of cobaltite-gersdorfite corresponding to ~550 °C. Oxygen isotope thermometry for the scheelite-quartz pairs yielded temperatures in the range from 390 to 440°C, similar to arsenopyrite thermometry of arsenopyrite II.

FI representing stage 1 and stage 2 mineralization are small (< 5 μm) and affected by subsequent quartz deformation and recrystallization. Optical study and micro-Raman analyses indicate CO_2-rich fluids with densities corresponding to a pressure decrease from 450 to ~200 MPa during the evolution of individual structural types of quartz veins. A small amount of water could have been leaked from the FI during ductile deformation.

Four ^{187}Re-^{187}Os ages on molybdenite indicate two periods of molybdenite deposition, one at 342-345 Ma and a younger period at 310 Ma. It is difficult to precisely relate these ages with $^{40}Ar/^{39}Ar$ ages obtained from stage 1 mineralization, because the $^{39}Ar/^{40}Ar$ data represent cooling ages and can be disturbed by subsequent periods of hydrothermal activity. Mineralogical studies indicate molybdenite deposition at early stage 3 mineralization.

Stage 3 mineralization, largely occurring as a relatively younger phase within quartz veins, is the mineralization of economic importance. The mineral assemblage molybdenite, high-temperature phase similar to cosalite, native Au and Bi, hedleyite and maldonite indicate temperatures of 260-380°C. Ore minerals are frequently associated with minor calcite. FI in this calcite and also numerous FI planes crosscutting several older quartz grains, are of the H_2O type, with salinities between 0.5 and 8.0 wt. % NaCl equiv., and Th between 170 and 300°C.

Stage 4 mineralization is represented by carbonate filling of youngest brittle fractures and steep faults. Carbonate is locally accompanied by minor adularia, fluorite, galena and pyrrhotite. FI data and the presence of open space features indicate pressures below 25 MPa. This hydrothermal stage was formed during and/or after the final stages of the uplift of the Moldanubian unit at ~295 Ma.

[Supported by Czechoslovak-American Science and Technology Program under project No. 94017.]

Author Index

Abart, R. *37*
Adams, M.C. *46*
Anderson, A.J. *46*
Audétat, A. *8*
Ayt Ougougdal, M. *22, 23*
Baker, T. *9*
Bakker, R.J. *10, 11*
Baksheev, I. *12*
Baldassaro, P.M. *13*
Banks, D. *17, 22, 23*
Barakat, A. *17*
Belozerova, O.Yu. *54*
Benison, K.C. *14*
Beurlen, H. *15*
Blackburn, W.H. *66, 67*
Bodnar, R.J. *13, 16, 18, 41, 58, 59, 69*
Boiron, M. *17, 22, 23, 31*
Brauer, N.A. *18*
Brennan, S.T. *19*
Brown, P.E. *40*
Buehn, B. *20*
Burnard, P.G. *65*
Burruss, R.C. *14*
Campbell, A.R. *21*
Canals, M. *50*
Cathelineau, M. *17, 22, 23*
Chevalier, P. *44*
Christoula, M. *55*
Cline, J.S. *60, 71*
da Silva, M.R.R. *15*
de Castro, C. *15*
Diamond, L.W. *10, 39*
Distler, V.V. *53*
Divaev, F.K. *24*
Dobes, P. *25*
Doukhan, J. *69*
Drakopoulos, M. *44, 49*
Duan, Z. *26*
Dubessy, J. *27, 31, 50*
Dugdale, A.L. *28*
Dunbar, N.W. *21, 30*
Durisova, J. *17, 73*
Ellendorff, B. *29*
Eschenbacher, A.J. *30*
Everett, C.E. *70*
Fabre, C. *31*
Fogliata, A.S. *32*
Gassymova, F.I. *33*
Goldstein, R.H. *14, 19*
Golias, V. *73*
González, M.M. *32, 34*
Goodell, P.C. *43*
Grebenschikova, V.I. *53*
Grimmer, J. *11*
Guerci, A. *23*
Günther, D. *8*
Hagemann, S.G. *28*
Halbach, P. *42*
Halls, C. *55*
Hardie, L.A. *67*
Heimbach, J.M. *35*
Heinrich C.A. *8*
Hoinkes, G. *37*
Huston, D.L. *38*
Ivanova, N.A. *24*
Jarmolowicz-Szulc, K. *36*
Kaindl, R. *37*
Kennedy, B.M. *47*
Khin Zaw *38, 63*
Klingenberg, I. *61*
Knoll, P. *37*
Krüger, Y. *39*
Kyle, P.R. *30*
Lamb, W. *27*
Lang, J.R. *9*
Laplace-Builhe, C. *50*
Large, R.R. *38*
Law, R.D. *18*
Leach, D. *25, 73*
Lee, T.J. *40*
Legrand, J.M. *62*
Leng, J. *41, 59*
Lowenstein, T.K. *66, 67*
Lowenstern, J.B. *30*
Lüders, V. *42*
Lueth, V.W. *43*
Mas, G. *32, 34*
Matel, N.L. *53*
McShane, C. *27*
Melnikov, F.P. *33*
Ménez, B. *44, 49*
Mernagh, T.P. *45*
Mitrofanov, G.L. *53*
Moissette, A. *31*
Moller, N. *26*
Moore, J.N. *46, 47*
Morales-Alvarado, M. *48*
Moravek, P. *17*
Mortensen, J.K. *9*
Mosbah, M. *44*
Nabelek, P. *64*
Nemerov, V.K. *53*
Norman, D.I. *47*
Pasteris, J.D. *14*
Pattrick, R.A.D. *65*
Perepelov, A.B. *54*
Philippot, P. *44, 49*
Pironon, J. *27, 50*
Polickovsky, V.S. *24, 72*
Popp, B. *27*
Populus, P. *44*
Pottorf, R.J. *41, 51*
Pracejus, B. *42*
Prohl, H. *52, 61*
Prokofiev, V. *12*
Prokofyev, V.Yu. *53, 54*
Prol-Ledesma, R.M. *48*
Rankin, A.H. *20, 55*
Roedder, E. *56*
Rose, S.R.A. *57*
Savarddinov, I.A. *72*
Schmidt, C. *58*
Schmidt, K. *29*
Sharma, A. *41, 59*
Shigehiro, M. *60*
Siemann, M.G. *29, 52, 61*
Silva, W.L. *62*
Singoyi, B. *63*
Sirbescu, M. *64*
Snee, L.W. *73*
Snigirev, A. *44, 49*
Spencer, R.J. *35, 57*
Spiridonov, A.M. *53*
Stein, H.J. *73*
Strnad, L. *73*
Thiéry, R. *27*
Thrower, C.D. *65*
Timofeeff, M.N. *66, 67*
Török, K. *68*
Turner, G. *65*
Umarov, B.N. *72*
Ustinov, V. *12*
Vanko, D.A. *44*
Viets, J. *25, 73*
Vityk, M.O. *41, 51, 69*
Walgenwitz, F. *50*
Weare, J. *26*
Whelan, J.F. *56*
Wilkinson, J.J. *70*
Willard, D.T. *71*
Wilson, S.A. *21*
Wopenka, B. *14*
Xavier, R.P. *62*
Yardley, B. *22*
Yudalevich, Z.A. *24*
Yudovskaya, M.A. *53*
Yusupov, R.G. *72*
Zak, K. *25, 73*

3 abstracts
inserted
at the
conference

TRACES OF EPIGENETIC HYDROTHERMAL ACTIVITY IN THE YUCCA MOUNTAIN VOLCANIC TUFFS: FLUID INCLUSIONS AND GAS CHEMISTRY EVIDENCE

DUBLYANSKY, Yuri. Institute of Mineralogy and Petrography, Russian Academy of Sciences, Siberian Branch, 2 Akademika Koptiuga Ave., Novosibirsk, 630090, Russia [dublyan@uiggm.nsc.ru]

Composite opal-quartz-calcite veinlets were sampled in the exploratory tunnel excavated in welded tuffs of the Yucca Mountain unsaturated zone. Veinlets typically exhibit several episodes of mineral deposition, recorded by alternating layers of: (1) botrioidal opal; (2) drusy quartz (crystals up to 2-4 mm); and (3) calcite (massive to spary; crystals up to 1.5 cm). Optical studies revealed four basic types of fluid inclusions in calcite: (1) all-gas; (2) gas-rich with variable but generally high V/L ratio (~0.4-0.8); (3) gas-liquid with low V/L ratio (~0.1 and less); and (4) all-liquid (with some 5 to 7 morphological subtypes).

Gas-rich and all-gas inclusions: Inclusions were broken open in glycerol and the change of the bubble volume was measured. Subsequently, the bubble was immersed in selective sorbents in order to remove: (1) CO_2; (2) CH_4 + other hydrocarbons; and (3) O_2. The content of a gas was estimated from the bubble volume decrease. The rest of the gas that was not dissolved in sorbents was attributed to a mixture N_2 + noble gases.

Large bubbles, occupying 40-80% of vacuoles in the Yucca Mountain subsurface calcites have been interpreted elsewhere as the air-water-carbon dioxide phase trapped during the growth of calcite from films of percolating rainwater. Our results (see Table) do not corroborate these early interpretations. On crushing, most bubbles decreased in volume which implies pressures <1 atm. A bubble from one inclusion slightly increased on crushing. The gas chemistry is not compatible with the environment of aerated unsaturated zone (for comparison, we present in the Table one analysis of the ambient air bubble). Gas-rich inclusions in the Yucca Mountain calcite were trapped from a fluid carrying both dissolved and gaseous methane. This implies crystallization from deep-seated methane-rich thermal water in the saturated zone.

Gas-liquid inclusions: All together, we obtained 82 homogenization temperatures from 6 calcite samples, with a significant part of the data coming from inclusions assembled in groups and having consistent V/L ratio. 89% of the data are bracketed by 35°C and 55°C, which suggests crystallization of calcite at temperatures exceeding the present day unsaturated zone temperatures. This result is in accord with previous (though meager) fluid inclusion data obtained by the DOE for calcites recovered from boreholes at -200-400 m. Calcite fluid inclusion temperatures suggest a paleothermal gradient of 150°-160°C/km, which is ten times the value of the present-day gradient in the unsaturated zone of 12°-15°C/km.

Conclusion: Textural and fluid inclusion data suggest deposition of calcite encountered in the Yucca Mountain exploratory tunnel was from deep-seated low-temperature thermal fluids. Both thermometric and gas chemistry data are incompatible with the vadose-zone setting.

Inclusion	Bubble		Volume		Content, vol. %	
#	D	mcm change	CO_2	CH_4	O_2	N_2
1	47	-120	2	80	0	18
2	84	-33	0	84	0	16
3	27	+2	0	83	0	17
4	54	-24	0	83	0	17
5	42	-27	13	80	0	7
6	30	-24	10	85	0	5
7	50	-20	15	22	0	63
ambient air	32	0	0	0	21	79

FLUID INCLUSIONS IN QUARTZ, SHIBANGOU GOLD ORE DEPOSIT, XIXIA, HENAN, P.R. CHINA

LIU WEI, and DEHUI ZHANG, Faculty of Earth Resources, China Univ. of Geosciences, Wuhan, P.R. CHINA, 430074 [ZYb@cug.edu.cn]

The Shibangou lode-type gold ore deposit Xixia, Henan Province, P.R. China, is hosted in ductile-brittle shear zones. Fluid inclusion characteristics in quartz and the nature of ore-forming fluids were deduced from 53 samples from this area. Microthermometry of fluid inclusions in quartz indicates five types of inclusions: 1. two-phase gas-rich inclusions (Type A), 2. two-phase liquid-rich inclusions (Type B), 3. polyphase inclusions that contain daughter crystals (Type C), 4. secondary, two-phase liquid-rich inclusions (Type D) and 5. secondary, one-phase liquid inclusions (Type E). Type A inclusions have homogenization temperatures of 330° to 350°C. Type B inclusions have homogenization temperatures of 170°C to 310°C. Type C inclusions have homogenization temperatures of 278° to 371°C. Type D inclusions have homogenization temperatures of 130° to 230°C. Type B inclusions have a salinity range of 4.4 to 13.6 NaCl equivalent wt%. Type C inclusions have a salinity range of 36.2 to 43.0 NaCl equivalent wt%. Type D inclusions have a salinity range of 4.6 to 11.3 NaCl equivalent wt%. Type E inclusions have a salinity range of 2.3 to 6.5 NaCl equivalent wt%. Ore-forming fluids are basically of the NaCl-KCl-H_2O system.

The most striking characteristic of the fluid composition is that in cations, K^+ and Na^+ are most numerous and in anions, F^- is slightly greater than Cl^-. In the gas phase, H_2O is dominant, followed by CO_2. δ D values of H_2O in inclusion fluids range from -24.00 to -37.30‰ and $\delta^{18}O$ of H_2O in the inclusions ranges from -2.49 to 1.99‰. $\delta^{13}C$ values for CO_2 gas in the inclusions are -11.12 to -14.59‰. These data suggest that the ore-forming fluid was a mixed fluid.

FLUID INCLUSIONS IN QUARTZ AND THE INFERENCE TO MINERALIZATION AT DEPTH, YINSHAN POLYMETALLIC DEPOSIT, JIANGXI PROVINCE, P.R. CHINA

LIU WEI[1], and DEHUI ZHANG[2], [1]China Univ, Geosciences, Beijing, 100083, P.R. China, [2]China Univ. of Geosciences, Wuhan, 430074, P.R. China. [Zyb@cug.edu.cn]

The Yinshan deposit, which is one of the large-scale Cu-Pb-Zn-Au-Ag polymetallic deposits, is located 2 km north of Dexing, Jiangxi Province, China. In this paper, new advances of fluid inclusions in quartz from the Yinshan deposit are presented. The study shows: 1. In polymetallic ore veins, fluid inclusions with halite daughter minerals have been discovered. 2. The fluid inclusion data may be divided into high salinity and low salinity groups. The salinity of saline fluid inclusions varies from 30 to 45 wt% NaCl equivalent and low salinity fluid inclusions vary from 2.86 to 14.4 wt% NaCl equivalent. 3. There are fluid inclusions containing liquid CO2 in polymetallic ore veins. 4. The homogenization temperatures of fluid inclusions range from 95° to 520°C displaying a very wide range. 5. The plot of homogenization temperature versus salinity indicates there are two groups of data and a curvilinear correlation between homogenization temperature and salinity. 6. A trend of decreasing salinity and homogenization temperatures is indicated.

From these data, the conclusions can be drawn as follows. The high salinities of fluid inclusions indicate that the hotter hydrothermal fluid is most consist with having a magmatic origin. The two groups of data of temperature and salinity have been attributed to mixing of a hot, saline fluid with a cool, dilute fluid. It is inferred that there may be a concealed igneous body and porphyry copper deposit at depth.