Guidebook

Society of Economic Geologists Foundation, Inc. Student-Dedicated Field Trip Course – IOCG and Copper-Silver Districts of Northern Chile

May 14 - 21, 2011

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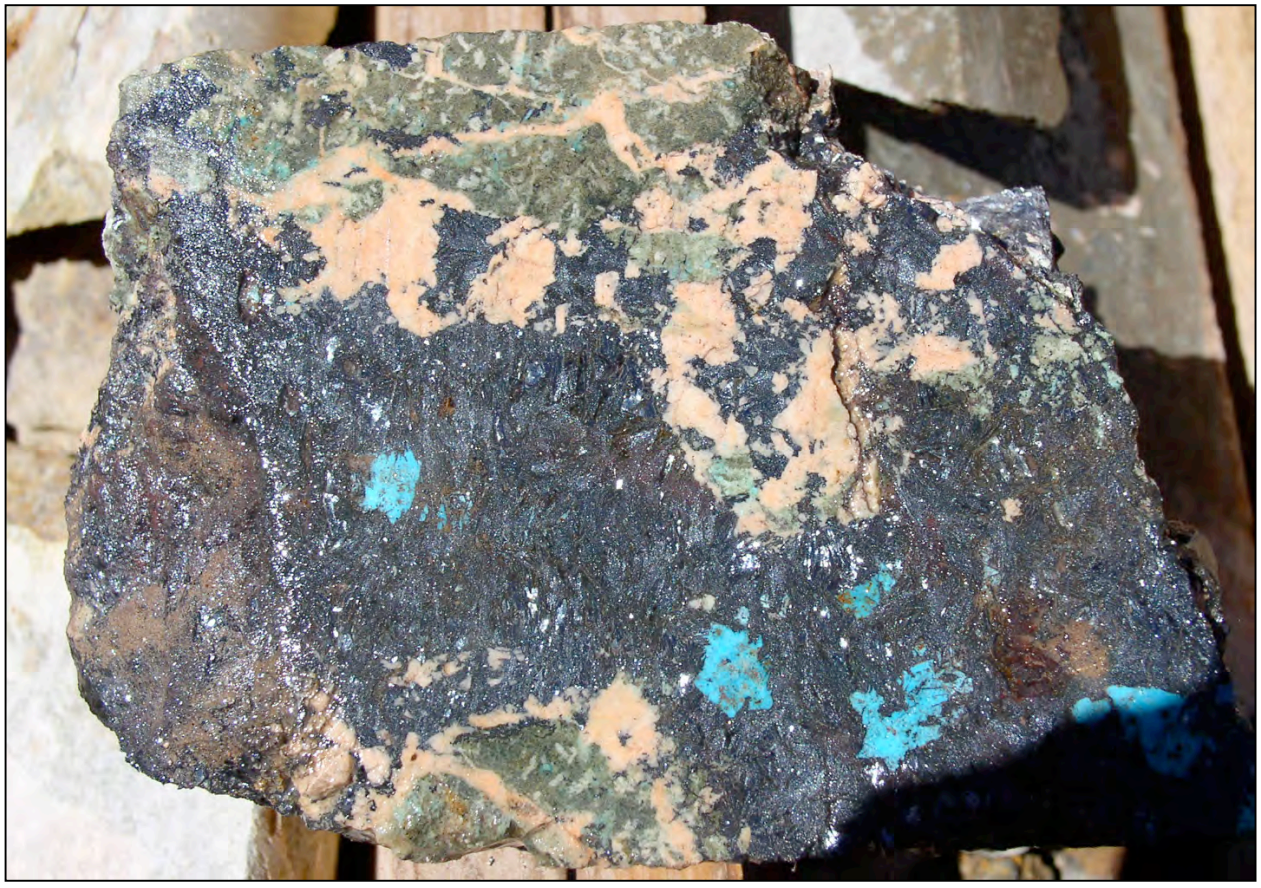
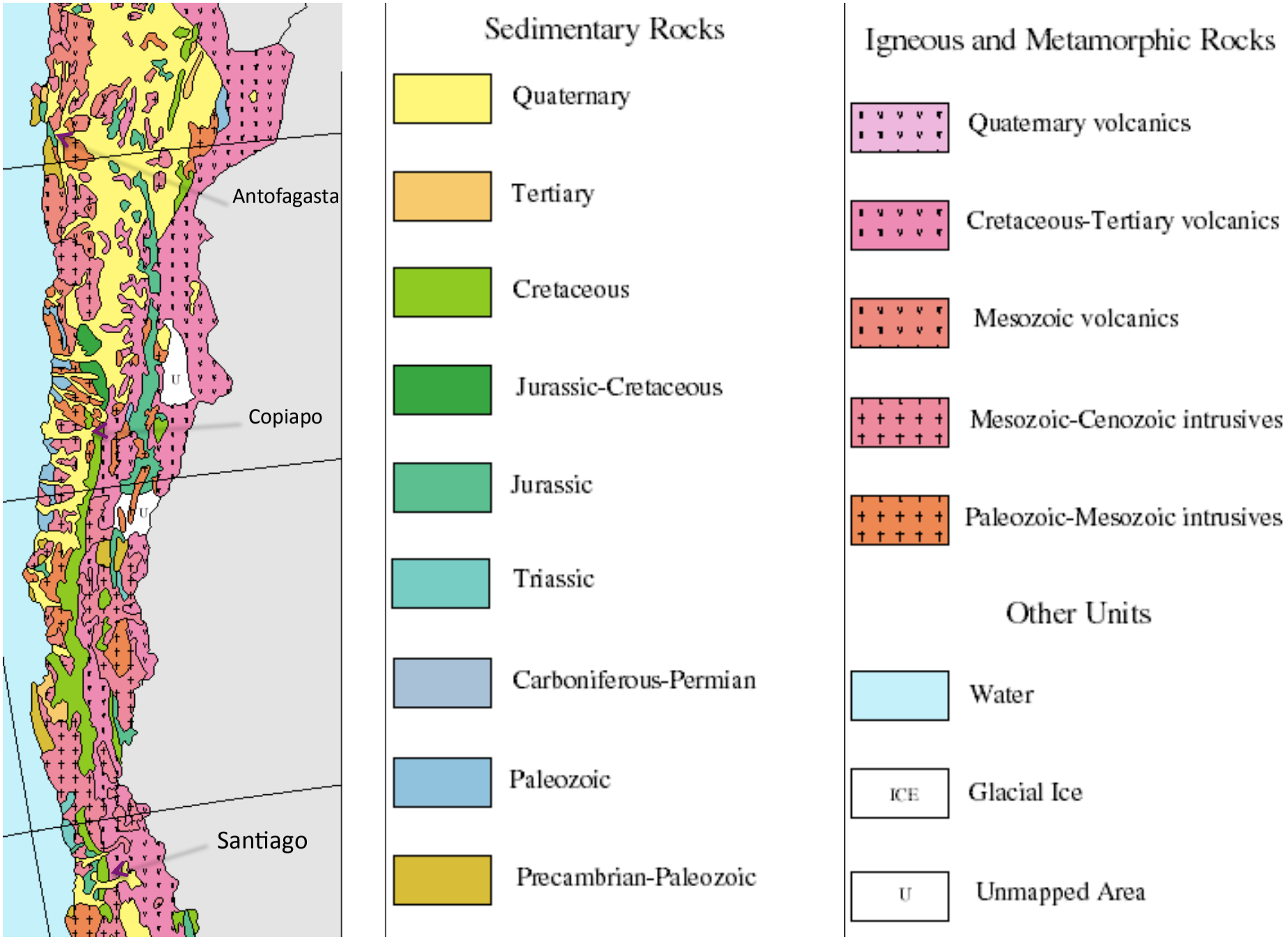


Geologic map for Central and Northern Chile (Modified from Andrew Alden 2001)



SEGF Student-dedicated Field Trip Course
IOCG and Copper-Silver Districts of Northern Chile

Welcome to the Society of Economic Geologists Foundation, Inc. Field Trip Course – IOCG and Copper-Silver Districts of Northern Chile, May 14 to 21, 2011. This field trip course is the eighth in Society of Economic Geologists Foundations Series that was established as a response to a student petition at the at the 2005 SEG Conference held in Keystone, Colorado, to provide support for field trips to important mining districts.

The course starts in Antofagasta. An organizational and safety meeting for all participants will take place at 7:00 pm on Saturday the 14th at the Hotel Tatio. The next morning you will pack up and we will depart from your hotel at 7 AM to visit Mina Julia. Roberto Aguilera Rojas will be our driver all week. Sunday evening we will stay in Taltal, a picturesque town on the beach. Tuesday we depart early again (7 AM) to visit the Altamira District and return to Taltal. Take only what you need for the day. On Tuesday we visit the Manto Verde deposit and head for Copiapó, which will serve as our base of operation for the rest of the trip. On Wednesday through Friday we will visit deposits in the Copiapó area. The field trip course ends on Friday evening with participants departing on Saturday.

Entrance to the mine sites usually follows a specific protocol; please be patient. At the mines we will receive safety training and a geological/engineering presentation. Do not take any pictures of the presentations unless and until we clear this point with company personnel. We will ask, but in general, participants can take pictures and collect samples on company property. Participants are responsible for their own samples (be aware of weight limits if you plan to take samples back with you).

We will have VERY LIMITED . . . REPEAT: VERY LIMITED . . . . space for luggage, so you should bring clothing and field gear ONLY IN DUFFLE BAGS - NO HARD-SIDED LUGGAGE. See you in Antofagasta.

Acknowledgements

*This field trip is generously supported through the Society of Economic Geologist Foundation through the **SEGF Student Field Trip Fund**. We also wish to thank the companies that provided access to their operations in Chile and the many company representatives that gave generously of their time to make this trip a success. Special thanks are due to Borden Putnam, Brian Hoal, John Thoms Vicky Sternicki, Joshua M. Coder, Raúl Venegas Carvajal, Florea Sgar, Cindy Gonzáles Salazar, Jose Cardenas, Roylester R Guerra Dubó, Constantin Isache, Ioan Filip, Nicolae Pop, and Roberto Aguilera Rojas.*

The Society of Economic Geologists Foundation

Luz

Franke

Mina Julia

Mina Carola

Las Pintadas

AngloAmerican

QuadraFNX Mining Ltd.

S.C. Minera Atacama Kozán

Erich U. Petersen

William X. Chávez, Jr.

Cover: IOCG ore, Altamira District

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Society of Economic Geologists Foundation, Inc.
"IOCG" and Copper – Silver Districts of Northern Chile Reprise
14 – 21 March, 2011

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Date	Itinerary	Overnight
14 May Saturday	**7:00 PM:** Assemble at **Hotel Tatio**, Antofagasta **Safety and Logistics Meeting** for all participants. **Lodging:** **Students**: **Hotel Costa Marfil** hotelcostamarfil@yahoo.es (Sra. Erika Corrales Poblete) – or Danitza Teléfono: 56-55-225569 (oficina) ó -283590 (oficina) ó 269-361 (público) **Professionals**: **Hotel Tatio** Avenida Grecia #1000 Telephone: (56-55)-419-111 <consultastatio@123.cl> Contact: Luís Castillo or Alejandro	Antofagasta
15 May Sunday	**7:00AM** – Depart for **Mina Julia Cu-Au vein system** Discuss " IOCG" styles and classification and ages in northern Chile. **Lodging:** **Students**: **Residencial Paraná** Contact: Sr. LLamil Jalil Nara Negrete (dueño): 56-55-613-604 Also**:** Sra. Rosita **Professionals**: **Hostería Taltal**: 56-55-611-173 or FAX: -625 Contact: Nury Cortes/Tanya; Marseilla Cabaña <lorens.caseres34@gmail.com>	Taltal
16 May Monday	**7:00AM** – Depart for **Altamira District and Franke andesite-hosted Cu-Ag system**; discuss copper systems hosted by volcanic rocks; redox settings.	Taltal
17 May Tuesday	**6:00AM** – Depart for **Manto Verde breccia-hosted copper-(gold) systems**. 'IOCG' systems discussion; What are "IOCG" systems? Atacama Fault Zone **Lodging**: **Students:** **Residencial Plaza**: Calle O'Higgins No. 670 Telephone: 56-52-212671 Contact: María Cortés Rojas **Professionals**: **Hotel La Casona** Calle O'Higgins No. 150 56-52-217-278 or 277 Contact: Pamela <reservas@lacasonahotel.cl	Copiapó
18 May Wednesday	**7:30AM** – Visit **Las Pintadas Cu-(Fe, Au) system**; compare with skarn systems and to other Punta del Cobre District ore deposits	Copiapó
19 May	**7:30AM** – Visit **Atacama Kozán Cu-(Fe, Au) (as cp-py-po) ore deposit**;	Copaipó

Thursday	compare this system to distinct Cu-(Au) ores of the Copiapó District.	
20 May Friday	**7:30AM** - Visit **Mina Carola structurally-controlled Cu-Fe-Au** deposit; ?vein system or "IOCG"? or what?	Copiapó
	Evening: Final dinner as SEGF Field Course participants.	
21 May Saturday	**End of Course – Participants Return on their own schedules**	

PARTICIPANT CHECKLIST AND NOTES:

- **Participants must arrive at the Hotel Tatio in Antofagasta by 7:00PM on the 14th of May** for a logistics and safety meeting.
- **All participants MUST – REPEAT…MUST - bring hardhat, STEEL-TOE boots, reflective vest, gloves, eye protection (not sunglasses for underground visit)**. **DO NOT plan to obtain these items during the course, as there is no time to do so!**
- Participants **must provide proof of insurance coverage valid in Chile PRIOR** to participation in the course. **Please bring your insurance card ID with you.**
- All participants must sign a **liability waiver form** that will be provided by SEGF prior to participation in the course.
- Participants from the U.S. will be required to pay a one-time **Reciprocity Fee** (around US$140) as part of the immigration entrance process into Chile; this is done in the Immigration area prior to entering the lines that lead to the immigration checkpoints.
- Participants will need to check on **Chilean visa requirements** well in advance of their travel to Chile; for some nationalities, the visa may be obtained on the flight to Chile.
- All participants will need to submit their passport information (name, country of issue) to SEGF so that this information may be passed along to the mining companies as a part of our mine entrance procedures.
- The weather in northern Chile during May is generally balmy and cool; with especially cool nights. Please bring layers of clothing for warm days and cool evenings.
- **Participants must bring along long pants and long-sleeve shirts for the mine visits.**
- Sunscreen, lip balm, sunglasses, and a hat or cap are strongly recommended.

Some additional information from your field trip leaders to assist with your arrival into Santiago, bus ticket transfers/purchase to travel from Santiago to Antofagasta and travels while in Chile.

- Remember to check on your visa requirements **WELL IN ADVANCE** of your travel to Chile.

♦ Remember, some countries' residents are charged a "Reciprocity Fee" upon entering Chile - one must pay this fee **BEFORE** passing through Immigration (sharp left at the foot of the stairs before entering the lines to the Immigration stations).

♦ Students would benefit greatly from the purchase of a tourbook/guidebook (with maps) of some sort (Lonely Planet, Fodor's etc.) prior to this course, so that they can know at least some of the customs and general travel information prior to their arrival in Santiago.

♦ It is highly recommended that students buy their bus tickets immediately upon arrival in Santiago.

The way to do this is:

1. Arrive SCL, collect baggage, go to kiosks in lower level arrival exit area; buy transfer bus ticket (usually on a company called TurBus, but several companies will have easy, inexpensive transport to Santiago downtown). DO NOT TAKE A TAXI UNLESS YOU BOOK THROUGH ONE OF THE AGENTS INSIDE THE AIRPORT – DO NOT TAKE AN OFFER OF A TAXI FROM ANY OF THE INDIVIDUALS WHO OFFER SUCH OUTSIDE OF BAGGAGE CLAIM. IF YOU INSIST ON TAKING A CAB, BOOK (AND PAY) FOR ONE AT THE KIOSKS OUTSIDE OF BAGGAGE CLAIM.

2. Get off the bus at the last stop, at the Estación Central Metro Station.

3. The Bus Station is a few blocks away (check with your tourbook), so ask the transfer bus driver or refer to a tourbook for directions on how to get to the Bus Station.

4. Upon arrival at the Bus Station, check for bus departures for Antofagasta, and purchase a ticket on a "Semi-Cama" style sleeper bus; these are inexpensive, comfortable, and reliable. Be sure to note the departure time, as buses keep to a strict departure timetable.

5. Students will arrive at the Bus Station in Antofagasta, and then can easily walk (approximately 2 blocks, uphill) to the Costa Marfil Hosteria, where they will staying the first night. Please note that it is not necessary to take a taxi (you will be charged about 2000 pesos for a five-minute walk). The Safety and Logistics Meeting is at the Hotel Tatio at 7:00 PM, and is a taxi ride from the Costa Marfil.

♦ You may change money at the airport in Santiago, either as you enter the Baggage Claim area or upon leaving the Customs area. You will need Chilean money (**do not** count on using a credit card!) for your personal expenses, including some meals, so **change money prior to your arrival in Antofagasta – there will be no time to do so during the field course**.

♦ Students are staying at the Costa Marfil hostería in Antofagasta (see address, above) – when you arrive, a room will have been assigned to you, so please use that room for your stay in Antofagasta (one night).

♦ Because we will be staying in hostels, please bring a towel, the usual toiletries, and a facecloth for your use; please pack lightly (easier to travel, too, with less baggage and weight). Laundry is available at the hostels where we will be staying.

Las Pintadas, Garnet with calcite.

Minerals Occurring in IOCG Deposits of Chile
(Supergene and Hypogene)

Copper (Fe, As) sulfates

Antlerite ..... $Cu_3SO_4(OH)_4$
Atacamite (paraatacamite, botallackite) . $Cu_2Cl(OH)_3$
Bonattite ..... $CuSO_4*3H_2O$
Brochanite ..... $Cu_4SO_4(OH)_6$
Chalcanthite ..... $CuSO_4*5H_2O$
Posnjakite ..... $Cu_4SO_4(OH)_6*H_2O$
Wroewolfeite (Langite) ..... $Cu_4SO_4(OH)_6*2H_2O$
Malachite ..... $Cu_2(CO_3)(OH)_2$
Azurite ..... $Cu_3(CO_3)_2(OH)_2$
Dioptase ..... $CuSiO_2(OH)_2$

Chalcosiderite (compare to tourquoise) .. $CuFe_6(PO_4)_4(OH)_8*4H_2O$
Libethinite..... $Cu_2PO_4(OH)$
Chrysocolla (mineraloid) ..... $Cu(Fe,Mn)O_x$-SiO_2-H_2O, with copper content varying from ~20-40 wt % Cu

Copiapite ..... $Fe_5(SO_4)_6(OH)_2*20H_2O$
Coquimbite ..... $Fe_2(SO_4)_3*9H_2O$
Goethite ..... a-FeOOH
Jarosite ..... $(K,Na)Fe_3(SO_4)_2(OH)_6$
Kröhnkite ..... $Na_2Cu(SO_4)_2*2H_2O$
Poitevinite ..... $(Cu,Fe,Zn)SO_4*H_2O$
Pseudomalachite ..... $Cu_5(PO_4)_2(OH)_4$

Ceruleite ..... $Cu_2Al_7(AsO_4)_4(OH)_{13}*12H_2O$
Turquoise ..... $CuAl_6(PO_4)_4(OH)_8*4H_2O$
Voltaite ..... $K_2Fe_8Al(SO_4)_{12}*18H_2O$

Scorodite ..... $FeAsO_4*2H_2O$
Chenevixite ..... $Cu_2Fe_2(AsO_4)_2(OH_4*H_2O$
Levandulite ..... $NaCaCu_5(AsO_4)_4Cl*5H_2O$

Cu sulfides & oxides

Bornite ..... Cu_5FeS_4
Chalcopyrite ..... $CuFeS_2$
Chalcocite ..... Cu_2S
Covellite ..... CuS
Cuprite ..... Cu_2O
Tenorite ..... CuO
Paramelanconite ..... Cu_4O_3

Silicates

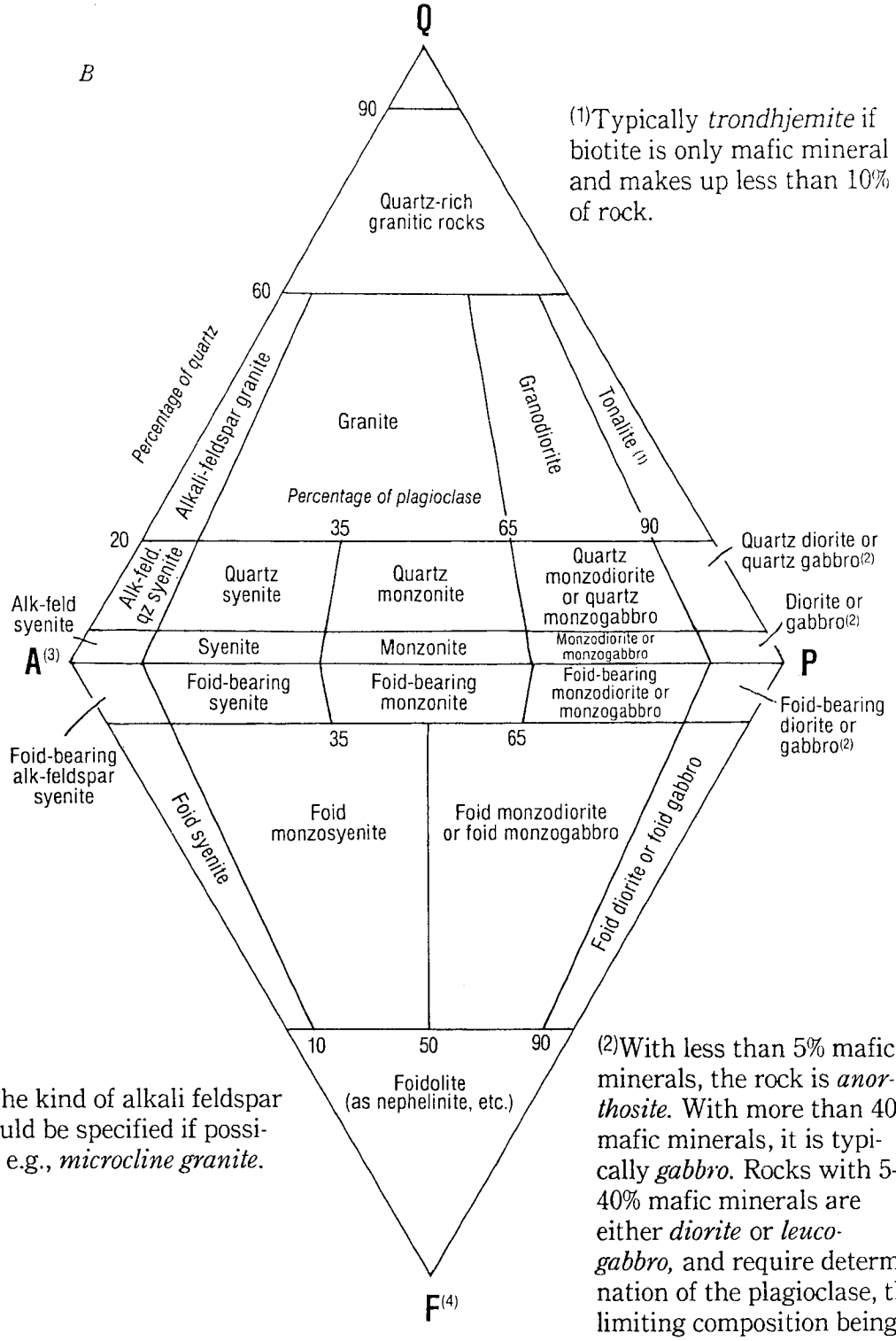
Alkali feldspar ..... $(K,Na)AlSi_3O_8$
Plagioclase ..... $(Na_xCa_{1-x})Al_{1-2}Si_{3-2}O_8$
Chlorite ..... $(Mg,Fe)_3(Al,Si)_4O_{10}(OH)_2*(Mg,Fe)_3(OH)_6$
Epidote ..... $Ca_2(Al,Fe)_3(SiO_4)_3(OH)$
Biotite ..... $KFe_3AlSi_3O_{10}(OH)_2$
Muscovite (sericite) ..... $KAl_3Si_3O_{10}(OH)_2$
Kaolinite ..... $Al_2Si_2O_3(OH)_4$

Other minerals

Alunite ..... $KAl_3(SO_4)_2(OH)_6$
Dumortierite ..... $Al_7(BO_3)(SiO_4)_3O_3$
Tourmaline ..... $(Na,Ca)(Li,Mg,Al)(Al,Fe,Mn)_6(BO_3)_3(Si_6O_{18})(OH)_4$

Magnetite after hematite Pucobre Mine

B

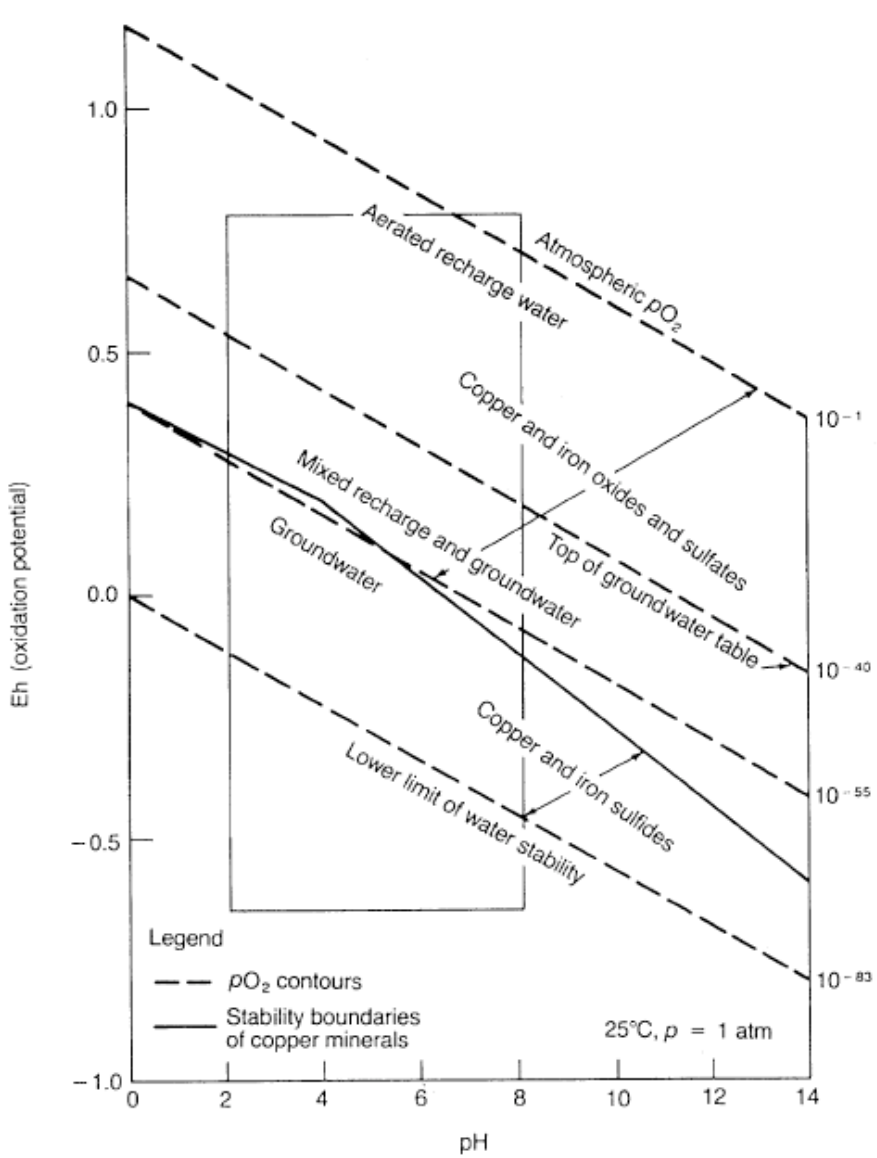


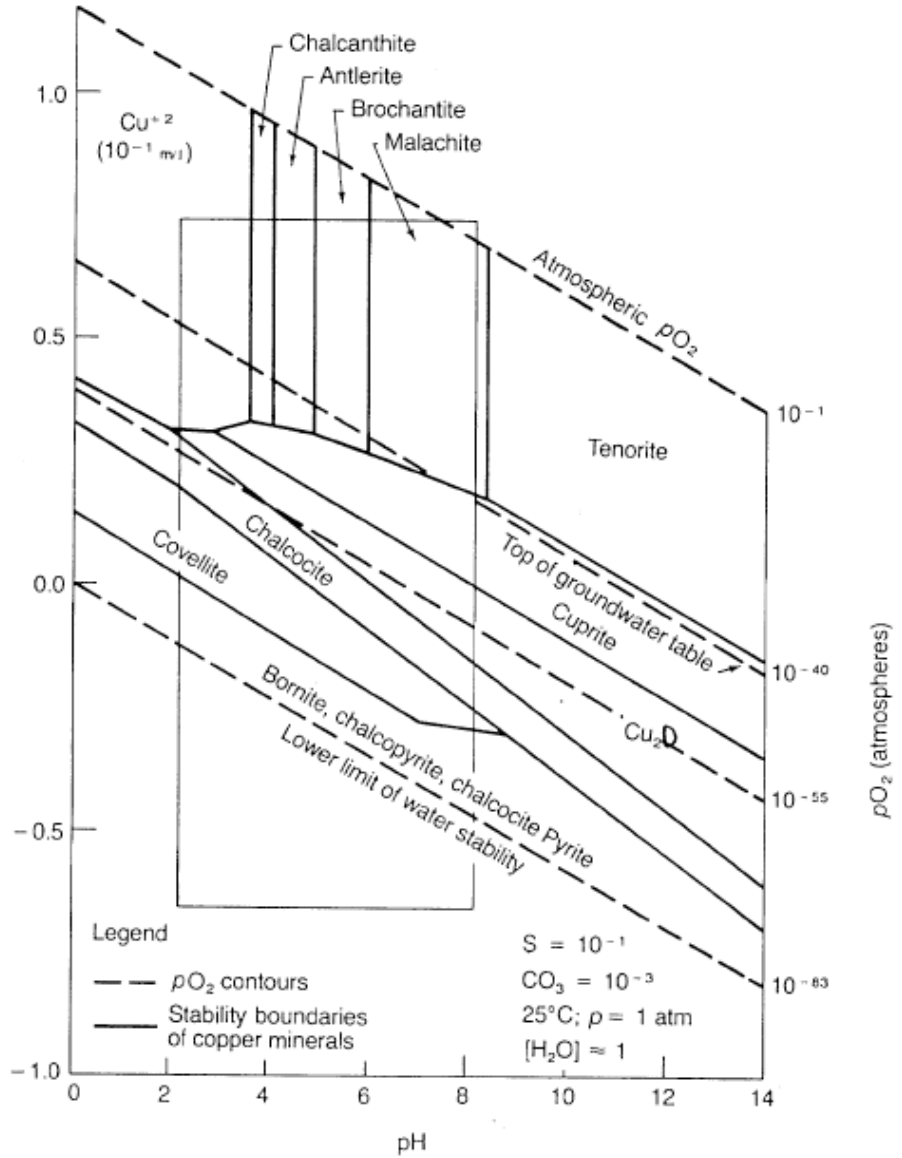
(1)Typically *trondhjemite* if biotite is only mafic mineral and makes up less than 10% of rock.

(2)With less than 5% mafic minerals, the rock is *anorthosite.* With more than 40% mafic minerals, it is typically *gabbro.* Rocks with 5-40% mafic minerals are either *diorite* or *leucogabbro,* and require determination of the plagioclase, the limiting composition being An_{50}.

(3)The kind of alkali feldspar should be specified if possible; e.g., *microcline granite.*

(4)The feldspathoid should be specified in each rock name; e.g., *nepheline syenite.*


Eh (oxidation potential)
1.0
0.5
0.0
−0.5
−1.0
0
2
4
6
8
10
12
14
pH
Aerated recharge water
Atmospheric pO_2
Copper and iron oxides and sulfates
Top of groundwater table
Mixed recharge and groundwater
Groundwater
Copper and iron sulfides
Lower limit of water stability
10^{-1}
10^{-40}
10^{-55}
10^{-83}
Legend
pO_2 contours
Stability boundaries of copper minerals
25°C, p = 1 atm


Chalcanthite
Antlerite
Brochantite
Malachite
Cu^{+2} (10^{-1} m/l)
Atmospheric pO_2
Tenorite
Top of groundwater table
Cuprite
Chalcocite
Covellite
Cu_2O
Bornite, chalcopyrite, chalcocite Pyrite
Lower limit of water stability
10^{-1}
10^{-40}
10^{-55}
10^{-83}
Legend
pO_2 contours
Stability boundaries of copper minerals
S = 10^{-1}
CO_3 = 10^{-3}
25°C; p = 1 atm
$[H_2O] \approx 1$
1.0
0.5
0.0
−0.5
−1.0
0
2
4
6
8
10
12
14
pH
pO_2 (atmospheres)

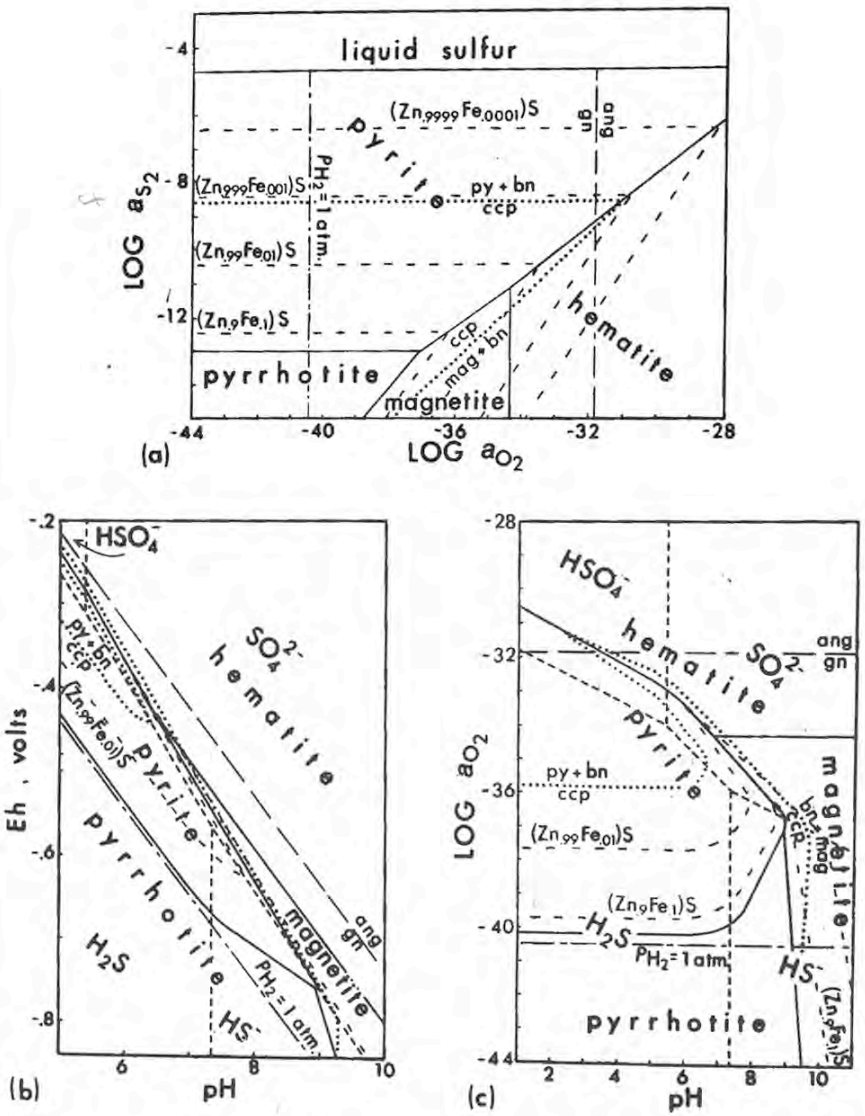


Fig. 7.5 Commonly employed methods of representing noninterfering, multicomponent equilibria. The same type of line is used to indicate each sort of reaction in each figure, but it is impractical to plot the full set of lines on each diagram. All of these diagrams are calculated for 250°C and an H_2O pressure of 40 bars. Abbreviations: py = pyrite; gn = galena; ang = anglesite; ccp = chalcopyrite; bn = bornite; mag = magnetite. The stability field for ferrous sulfate would appear in (a), but has not been included; it would be off the diagrams at low pH in (b) and (c).

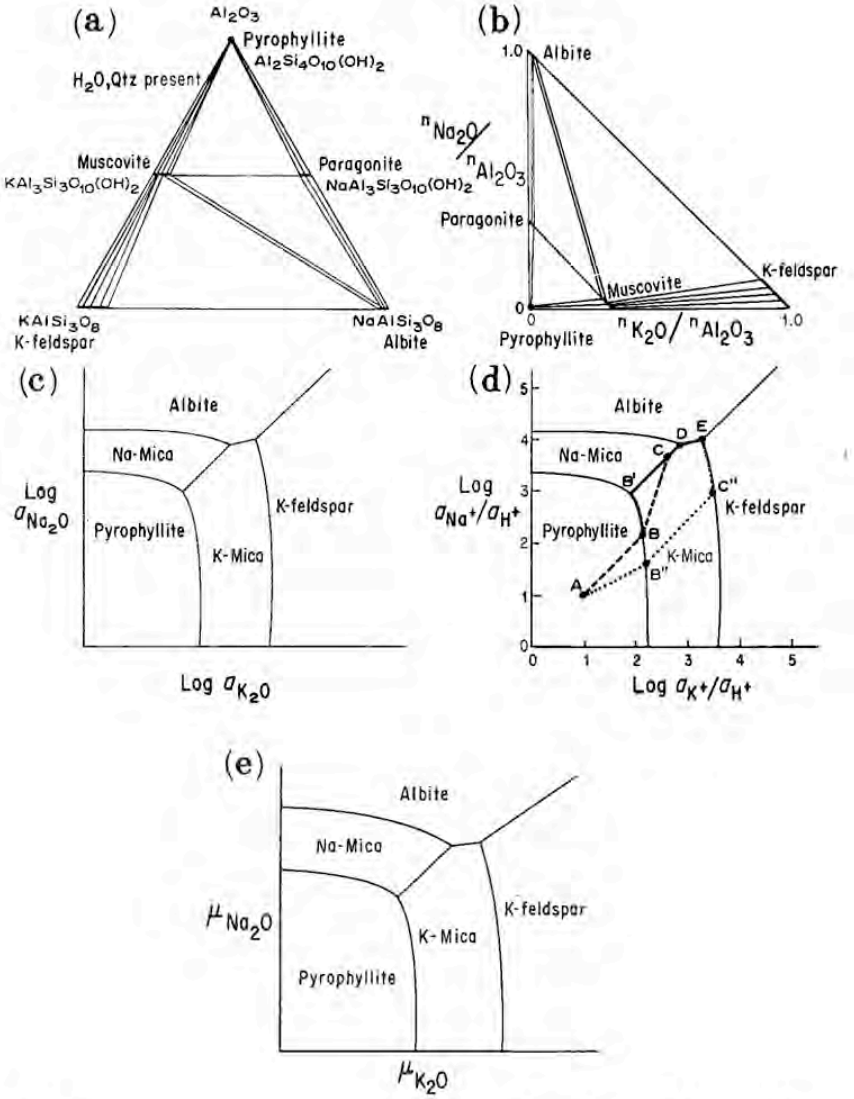
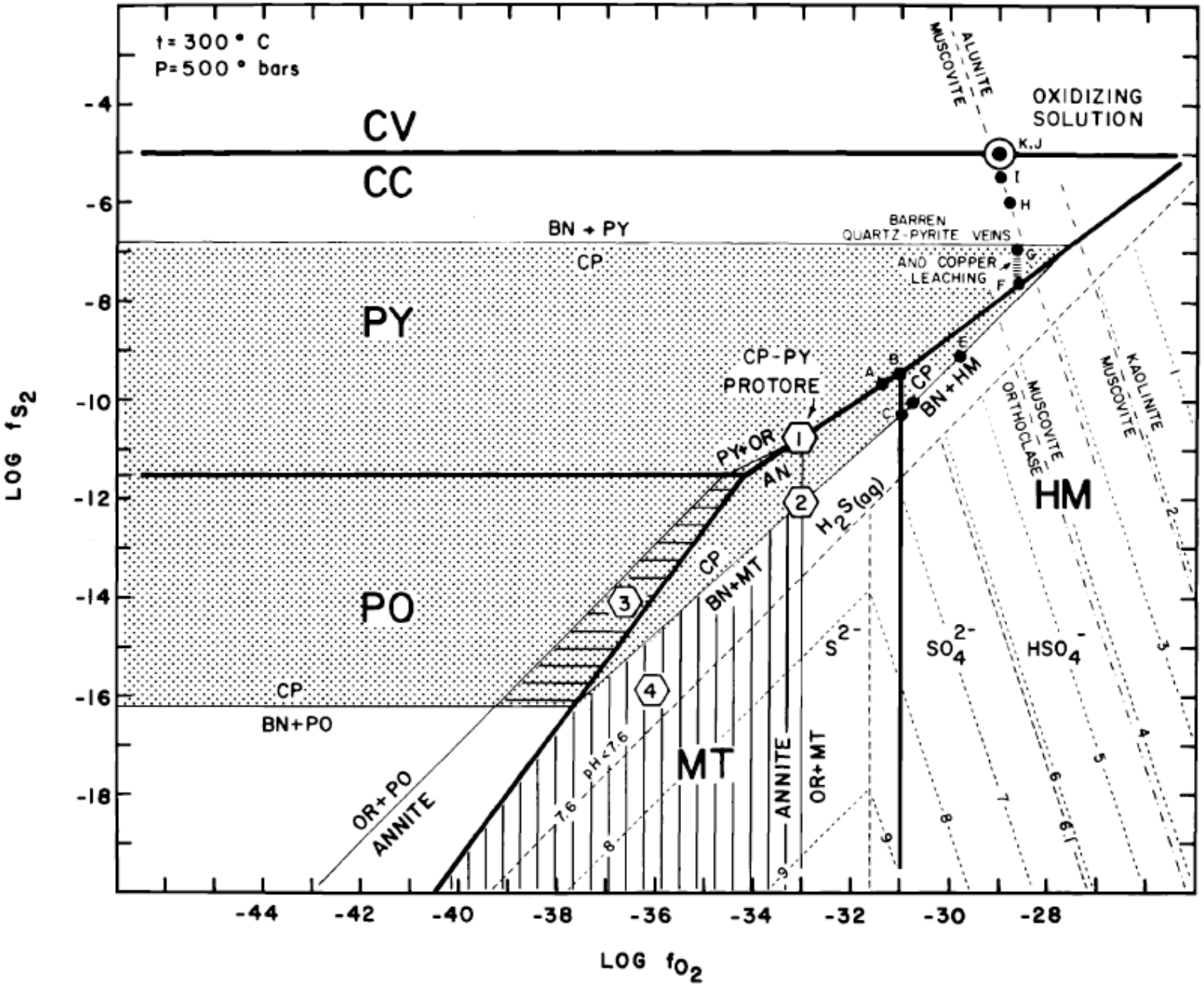


Fig. 5.5 Schematic stability relations in the system K_2O-Na_2O-Al_2O_3-SiO_2-H_2O-HCl at 400°C and 1 kb. Pyrophyllite is metastable. (a) Triangular mole fraction diagram, showing solid assemblages with quartz present. (b) Similar plot of molar Na_2O/Al_2O_3 vs. K_2O/Al_2O_3. (c) Stability of phases as a function of a_{Na_2O} vs a_{K_2O}. (d) Stability of phases as a function of log a_{Na^+}/a_{H^+} vs log a_{K^+}/a_{H^+}. See text for discussion of the paths of solution composition during reaction of solution A with a mixture of feldspars. (e) Stability as a function of μ_{Na_2O} vs μ_{K_2O}. Figures based on data in Helgeson (1974), Meyer and Hemley (1967), and Montoya and Hemley (1974).


t = 300 ° C
P = 500 ° bars
CV
CC
OXIDIZING SOLUTION
ALUNITE
MUSCOVITE
K,J
I
H
BN + PY
BARREN QUARTZ-PYRITE VEINS
AND COPPER LEACHING
G
F
CP
PY
CP-PY PROTORE
A
B
C
CP
BN+HM
MUSCOVITE ORTHOCLASE
KAOLINITE MUSCOVITE
HM
PY+OR
AN
1
2
$H_2S(aq)$
CP
BN+MT
PO
3
4
S^{2-}
SO_4^{2-}
HSO_4^-
CP
BN+PO
MT
OR+PO
ANNITE
7.6 - pH < 7.6
8
ANNITE
OR+MT
9
LOG f_{S_2}
LOG f_{O_2}
-4
-6
-8
-10
-12
-14
-16
-18
-44
-42
-40
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-36
-34
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-30
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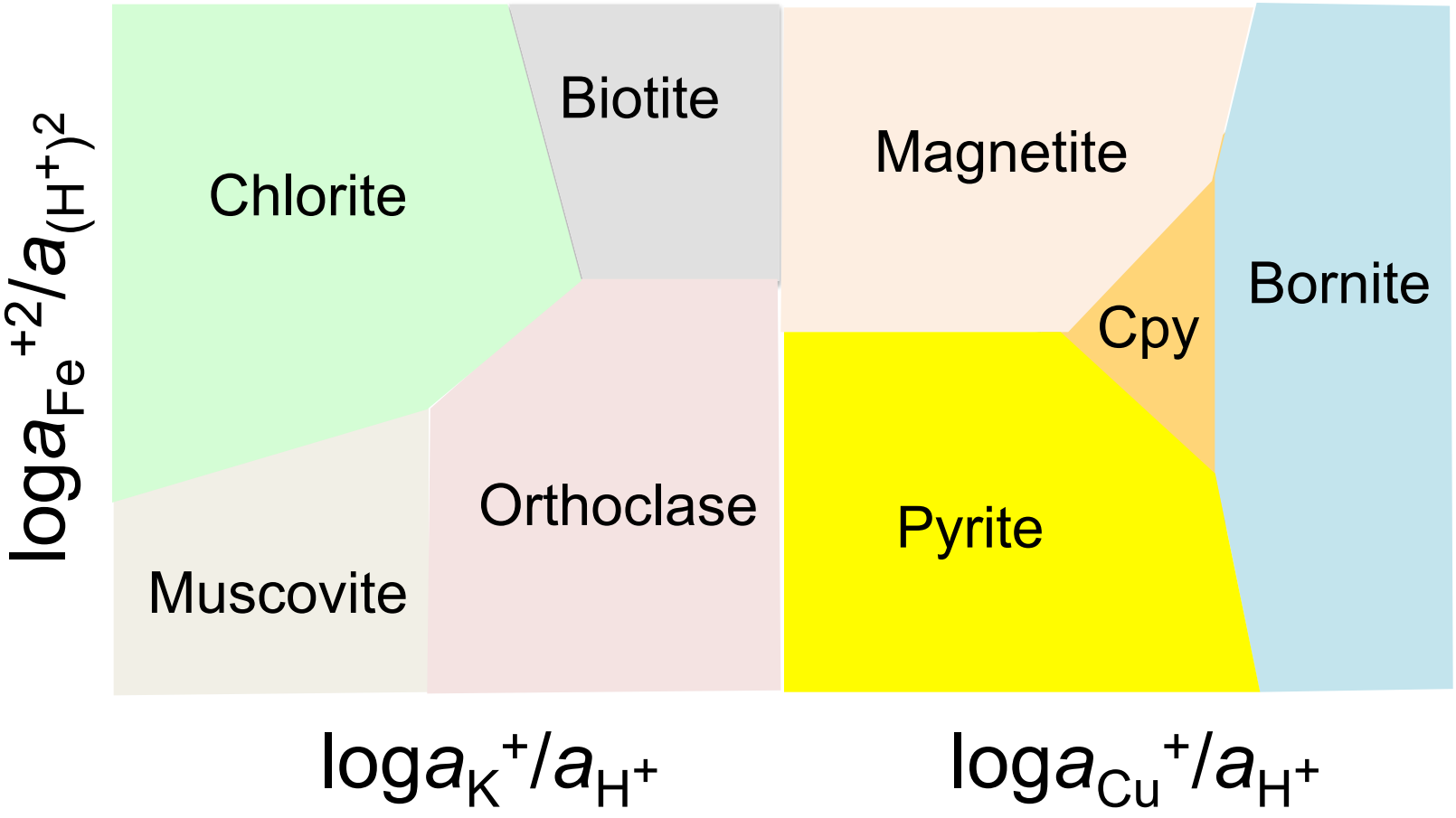
At the end of the trip, and as soon as possible, please send a brief e-mail to Borden Putnam with a copy to Brian Hoal and John Thoms describing your experience on the trip and acknowledging the support of the Society of Economic Geologists. This is very important, as the feedback received by SEG is critical for the planning of future field course trips. You will also find that maintaining contact in this manner will greatly benefit your career whatever course it may follow. Your note may be in your native language.


Chlorite
Biotite
Magnetite
Bornite
Cpy
Orthoclase
Pyrite
Muscovite
$\log a_{Fe}^{+2}/a_{(H^+)^2}$
$\log a_{K}^{+}/a_{H^+}$
$\log a_{Cu}^{+}/a_{H^+}$