



Guidebook

Field Mapping in Porphyry Copper Environments

Cerro Colorado Mine, Chile

August 11-14, 2002

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Field Mapping in Porphyry Copper Environments

Participants

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Itinerary

11 August, Sunday

11:00 AM	Airport Pickup, Drive to Mamiña (Refugio del Salitre)
1:00 PM	Depart Holiday Inn Express for Mamiña (Refugio del Salitre)
5:30 PM	Organizational meeting

12 August, Monday

6:30 AM	Breakfast
7:00 AM	Depart from Mamiña for Cerro Colorado
7:30 AM	Check in at Cerro Colorado, Mine Safety
9:00 AM	Mapping I
1:30 PM	Lunch
1:30 PM	Mapping II
5:00 PM	Depart Cerro Colorado for Refugio del Salitre
	Evening Session

13 August, Tuesday

6:30 AM	Breakfast
7:00 AM	Depart from Mamiña for Cerro Colorado
7:30 AM	Mapping III
1:30 PM	Lunch
1:00 PM	Mapping IV
5:00 PM	Depart Cerro Colorado for Refugio del Salitre
	Evening Session

14 August, Wednesday

6:30 AM	Breakfast
7:00 AM	Depart from Mamiña for Cerro Colorado
7:30 AM	Mapping V: Leached Capping / Core Review
1:30 PM	Lunch
3:00 PM	Depart for Airport

Useful References

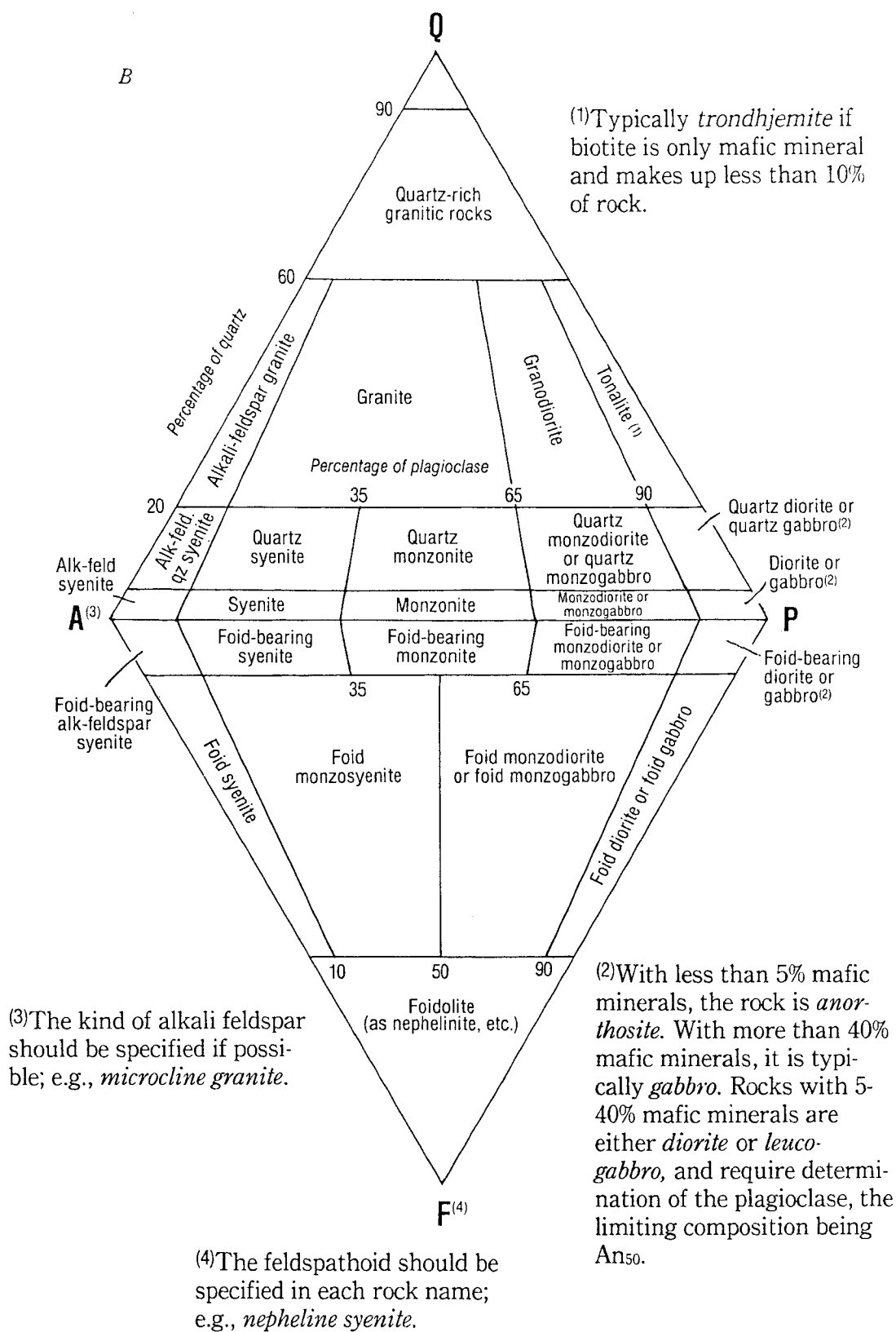
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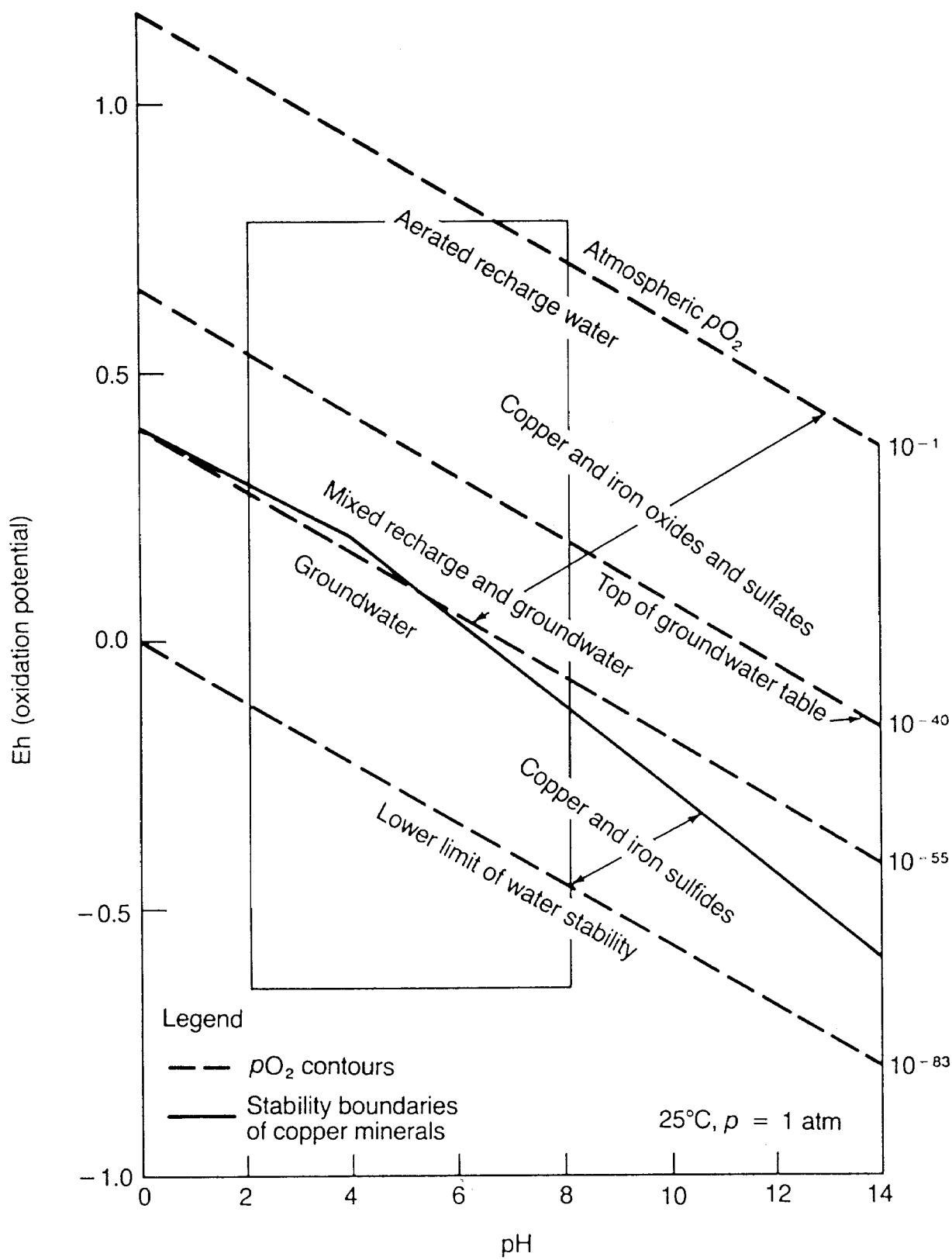
Some Common Mineral Formulas

Chlorite	$(\text{Mg,Fe})_3(\text{Al,Si})_4\text{O}_{10}(\text{OH})_2 \cdot (\text{Mg,Fe})_3(\text{OH})_6$
Biotite.....	$\text{KFe}_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$
Muscovite.....	$\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$
Kaolinite.....	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$
Alkali feldspar.....	$(\text{K,Na})\text{AlSi}_3\text{O}_8$
Plagioclase	$\text{CaAl}_2\text{Si}_2\text{O}_8$
Dumortierite.....	$\text{Al}_7\text{O}_3(\text{BO}_3)(\text{SiO}_4)_3$
Tourmaline.....	$(\text{Na,Ca})(\text{Li,Mg,Al})(\text{Al,Fe,Mn})_6(\text{BO}_3)_3$ $(\text{Si}_6\text{O}_{18})(\text{OH})_4$
Bornite	Cu_5FeS_4
Chalcopyrite.....	CuFeS_2
Chalcocite	Cu_2S
Covellite.....	CuS
Cuprite	Cu_2O
Tenorite.....	CuO

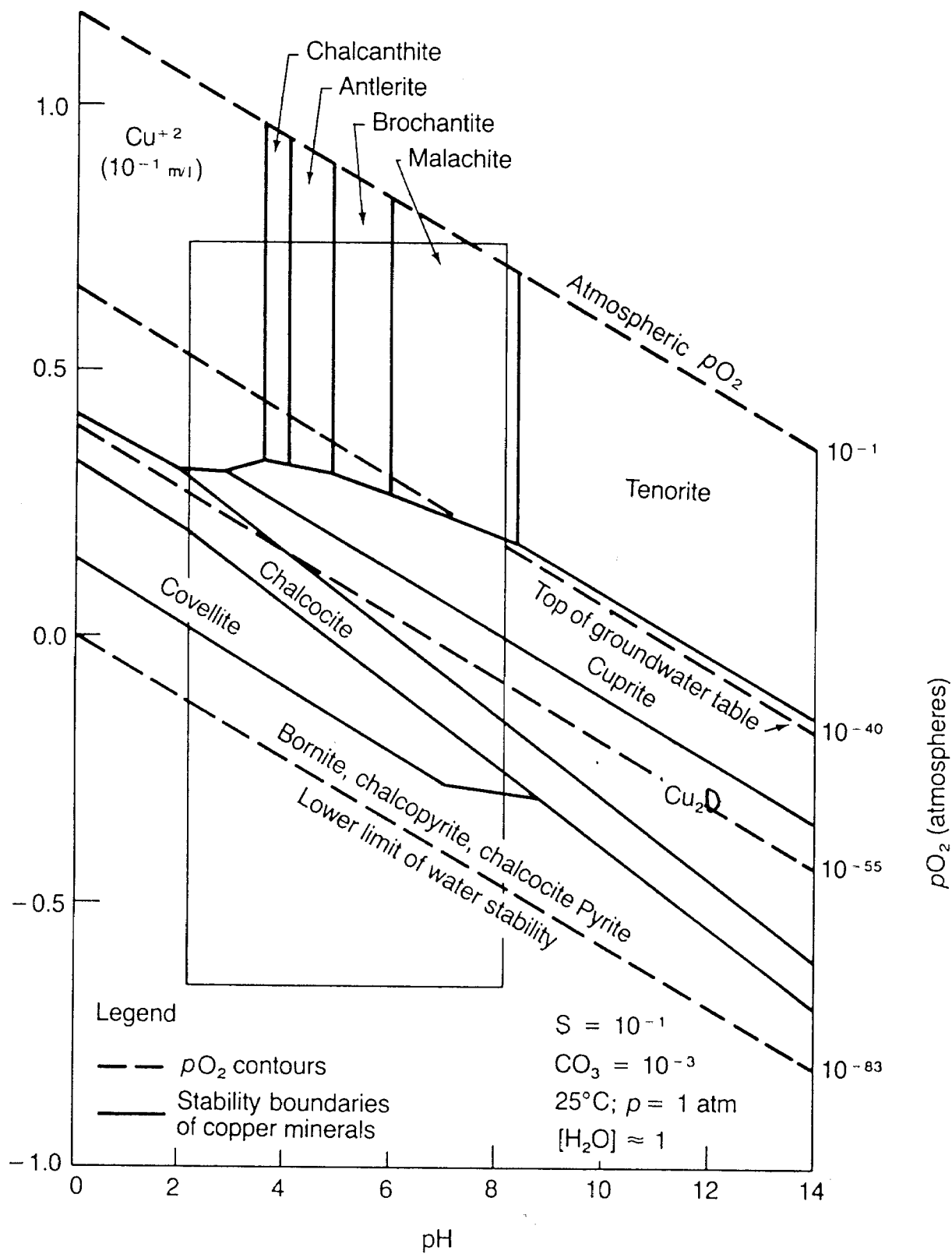
**Minerals Commonly Found in the Oxide Zone of Copper
Deposits**

Alunite	$\text{KAl}_3(\text{SO}_4)_2(\text{OH})_6$
Antlerite	$\text{Cu}_3\text{SO}_4(\text{OH})_4$
Atacamite (paraatacamite, botallackite)	$\text{Cu}_2\text{Cl}(\text{OH})_3$
Bonattite.....	$\text{CuSO}_4 \cdot 3\text{H}_2\text{O}$
Brochanite	$\text{Cu}_4\text{SO}_4(\text{OH})_6$
Ceruleite.....	$\text{Cu}_2\text{Al}_7(\text{AsO}_4)_4(\text{OH})_{13} \cdot 12\text{H}_2\text{O}$
Chalcanthite	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
Chalcosiderite (compare to turquoise).....	$\text{CuFe}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$
Chenevixite	$\text{Cu}_2\text{Fe}_2(\text{AsO}_4)_2(\text{OH})_4 \cdot \text{H}_2\text{O}$
Chrysocolla (mineraloid)	$\text{Cu}(\text{Fe}, \text{Mn})\text{O}_x - \text{SiO}_2 - \text{H}_2\text{O}$, with copper content varying from ~20-40 wt % Cu
Copiapite.....	$\text{Fe}_5(\text{SO}_4)_6(\text{OH})_2 \cdot 20\text{H}_2\text{O}$
Coquimbite.....	$\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$
Goethite.....	$\alpha\text{-FeOOH}$
Jarosite	$(\text{K}, \text{Na})\text{Al}_3(\text{SO}_4)_2(\text{OH})_6$
Kröhnkite	$\text{Na}_2\text{Cu}(\text{SO}_4)_2 \cdot 2\text{H}_2\text{O}$
Levandulite	$\text{NaCaCu}_5(\text{AsO}_4)_4\text{Cl} \cdot 5\text{H}_2\text{O}$
Libethinite.....	$\text{Cu}_2\text{PO}_4(\text{OH})$
Paramelanconite.....	Cu_4O_3 (see tenorite (CuO) and cuprite (Cu_2O))
Poitevinite	$(\text{Cu}, \text{Fe}, \text{Zn})\text{SO}_4 \cdot \text{H}_2\text{O}$
Posnjakite.....	$\text{Cu}_4\text{SO}_4(\text{OH})_6 \cdot \text{H}_2\text{O}$
Pseudomalachite	$\text{Cu}_5(\text{PO}_4)_2(\text{OH})_4$
Scorodite	$\text{FeASO}_4 \cdot 2\text{H}_2\text{O}$
Turquoise	$\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$
Voltaite.....	$\text{K}_2\text{Fe}_8\text{Al}(\text{SO}_4)_{12} \cdot 18\text{H}_2\text{O}$
Wroewolfeite (Langite).....	$\text{Cu}_4\text{SO}_4(\text{OH})_6 \cdot 2\text{H}_2\text{O}$





(a)



(b)

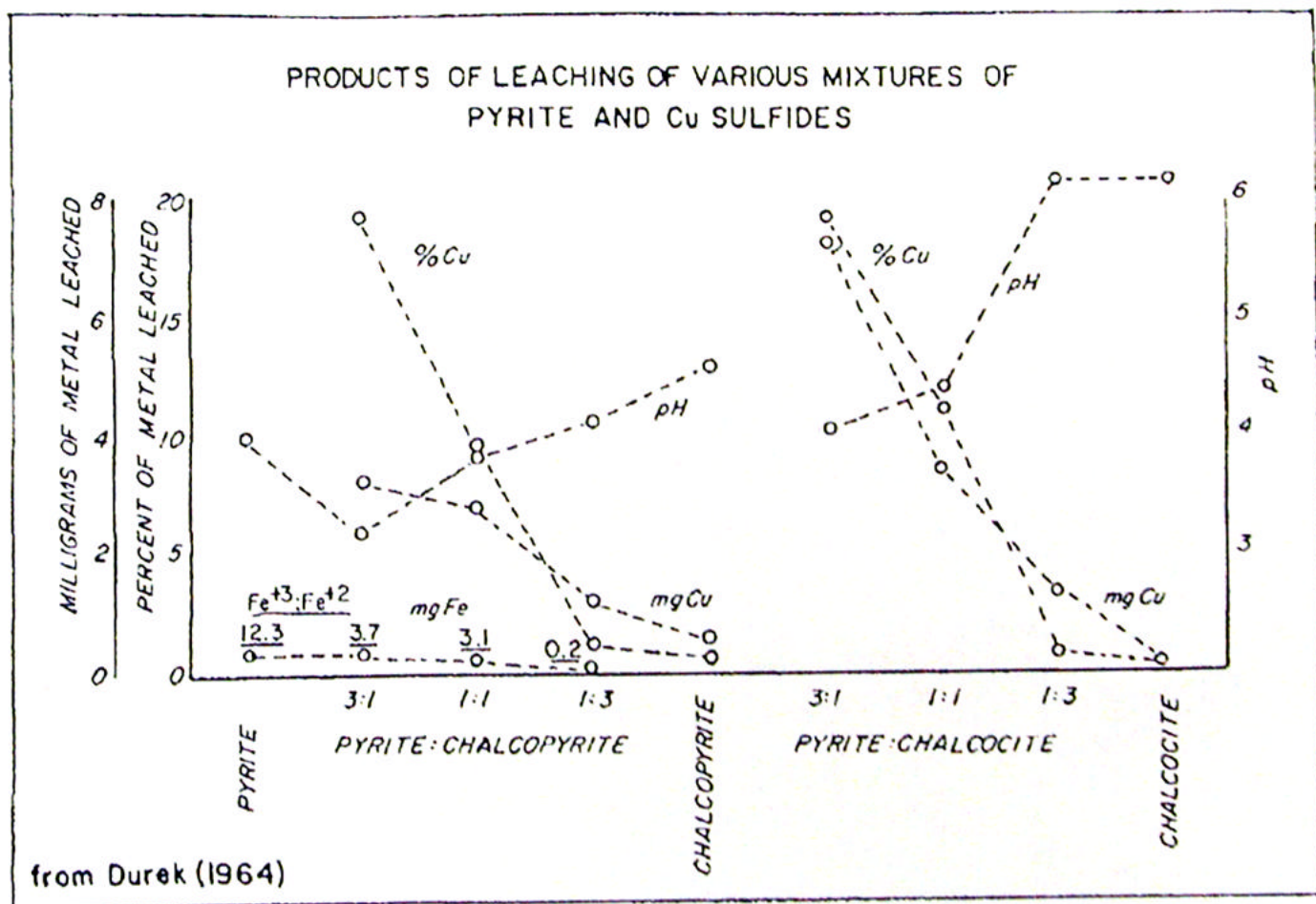


Figure 4. Copper solubility diagram for mixtures of various proportions of chalcopyrite and pyrite (left) and chalcocite and pyrite (right). Values

across the bottom of the left side of the figure are ferrous-ferric ratios determined in leach solutions. Redrafted from Durek (1964).

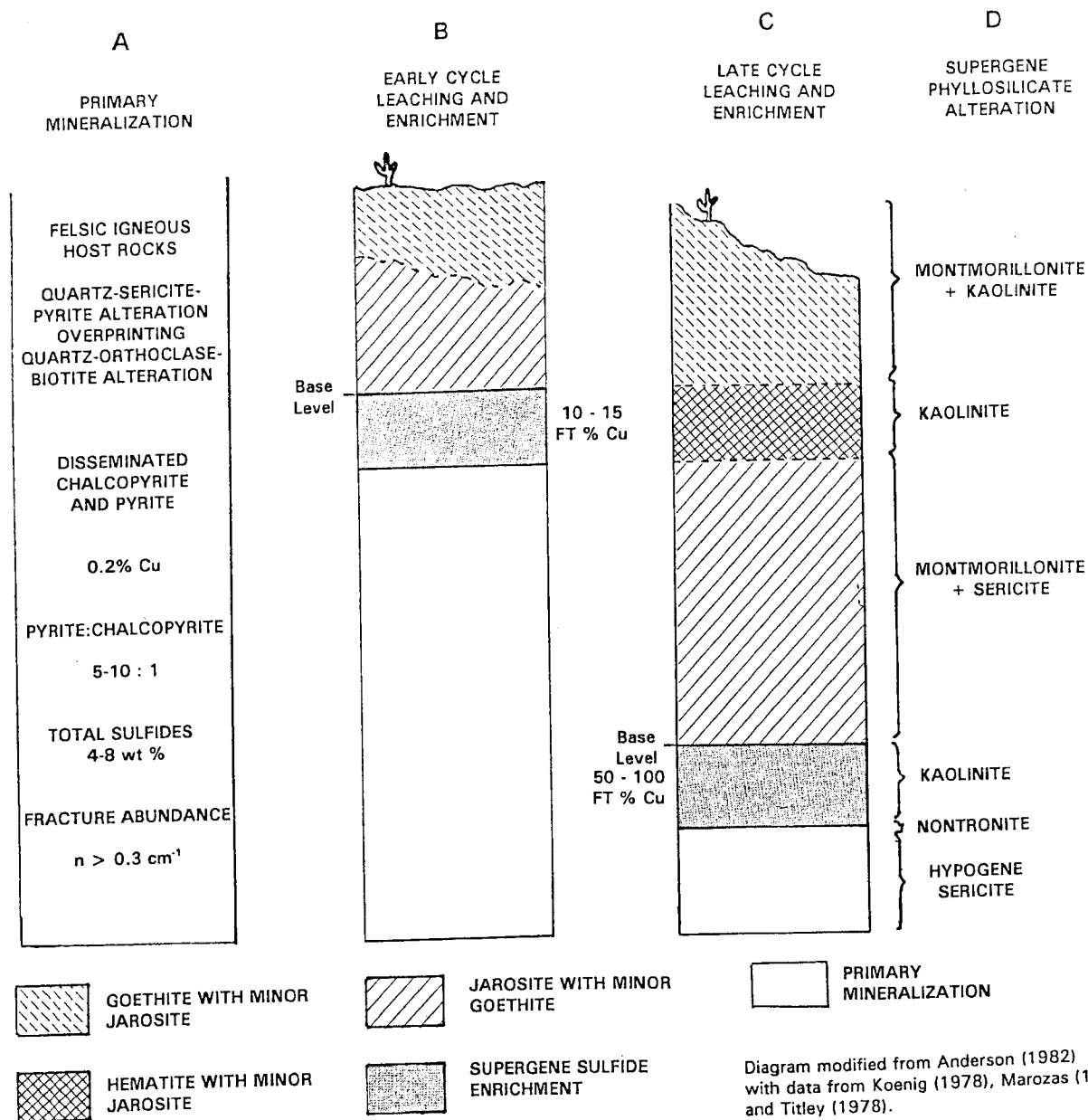


Figure 1. Generalized vertical sections showing relevant characteristics of: (A) a hypogene profile through quartz-sericite-pyrite altered felsic igneous rocks; (B) early stage weathering and development of early cycle enrichment; and (C) late cycle enrichment. Column D shows locations of principal phyllosilicate alteration phases across the profiles. Profiles B and C show the

position of early and late supergene blankets with weathering of Data are generalized from the authors' observations, mineralogic Koenig (1980), a study at North San Xavier deposit, and the Marozas (1982) at Silver Bell. No specific vertical scale is implied. files may range from 50 meters to several hundreds of meters in thi

Exercise:

Collection and Interpretation of Structural Data using "Titley Squares"

Ejercicio:

Recolección e interpretación de datos estructurales usando "Cuadros Titley"

This exercise asks one to collect standard fracture density information - but with the caveat that we will quantify the structural data obtained using the methods described by Heidrick and Titley (1982). The method is this: using squares having dimensions of 50 cm by 50 cm, one collects the total length of fractures occurring in four orientations. These directions are up-down, left-right, and the two diagonal directions. One sums the total fracture lengths measured, and divides by the total area of the square, or 2500 cm². This gives a quantitative value of fracture occurrence, as given in length/area, having therefore units of (length)⁻¹. Note that one measures all fracture types, including veinlets of various types, as well as "clean" fractures.

This information is collected at various areas within the mine, and point values in (length)⁻¹ are plotted and contoured (as at Sierrita, Arizona; Titley, 1999), showing the spatial changes in fracture density within an ore deposit, or within a specific intrusion or rock unit.

For this exercise, please measure - and compare your measurements - the fracture densities for each of the "Titley Squares" we have prepared. Can you explain the variation in fracture densities observed, even though we measured only a small area of the mine?

En este ejercicio, medimos, en una manera cuantitativa, la densidad de fracturas en cuadros nombrados "Titley Squares" (véase Heidrick and Titley, 1982). La idea medir el largo de fracturas (fracturas abiertas, vetillas) dentro de un área cuadrada, en este caso 50 cm por 50 cm, ó 2500 cm². Calculamos entonces la razón: (largo total de fracturas) dividido por (área del cuadro), que nos da un número en (largo)⁻¹.

Este número se puede plotear, como una indicación de la distribución de la densidad de fracturas según área en el yacimiento ó el prospecto, así como hecho Titley en el yacimiento tipo pórfido de cobre Sierrita (1999).

Al plotear estos datos de la Mina, ¿por qué hay una diferencia importante en la densidad de fracturas que hemos medido, a pesar de que el área del yacimiento que hemos estudiado es relativamente pequeño?

Iron Oxide Characterization Chart

The identification of iron oxides is critical in the interpretation of leached capping and gossan protolith mineralogy. By collecting iron oxide “smudges” from various geochemical environments, one can characterize the geochemical setting of weathering-related oxidation; this, in turn, permits one to interpret the potential for metals mobility attributable to supergene oxidation and transport.

Use the squares below for iron oxide smudges derived from leached outcrops and drill hole intervals, comparing the field smudges to those of the standard iron oxides shown. Note that the standard smudges are derived from leached capping environments, and represent XRD-analysed end-member iron oxides. Mixtures of red hematite, goethite, and jarosite will produce the gradational colors as shown in the standard box. Remember that the *complete* oxidation of one mole of pyrite will produce four moles of protons (H^+), and that the oxidation of other sulfides will always result in lesser total acid production *because of the important ferrolysis of Fe^{+++}* . Also, all geochemical roads lead to goethite as a stable iron oxide, although *dehydration* of goethite produces red hematite as an end product.

