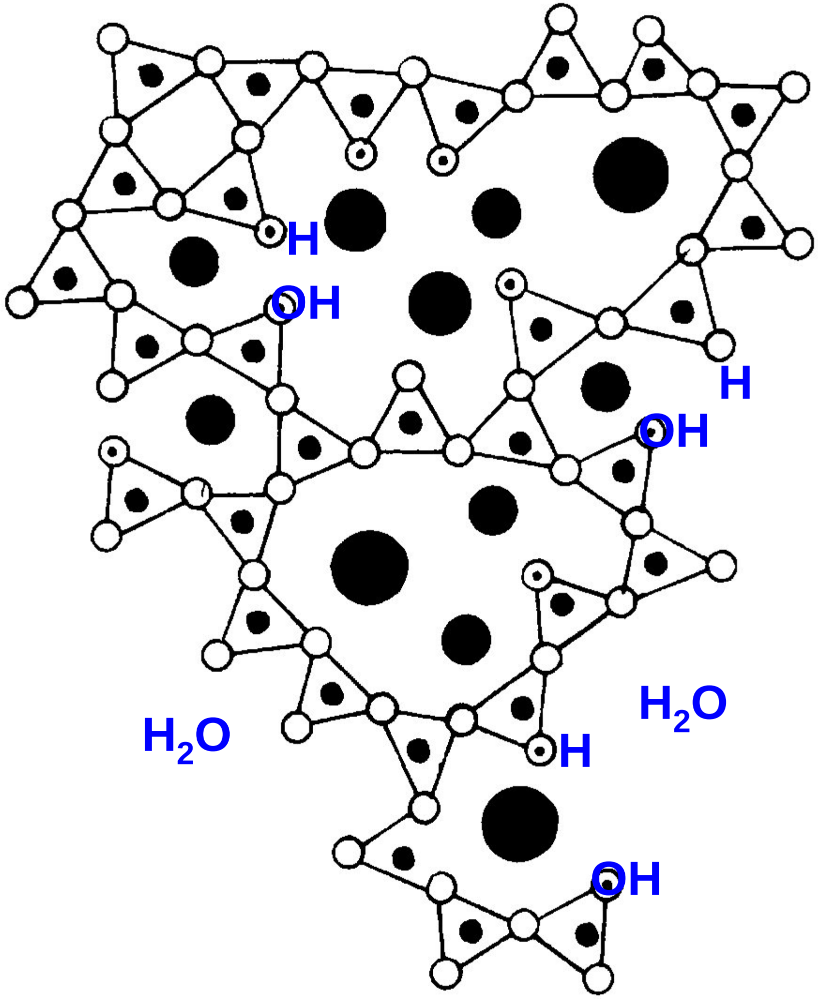
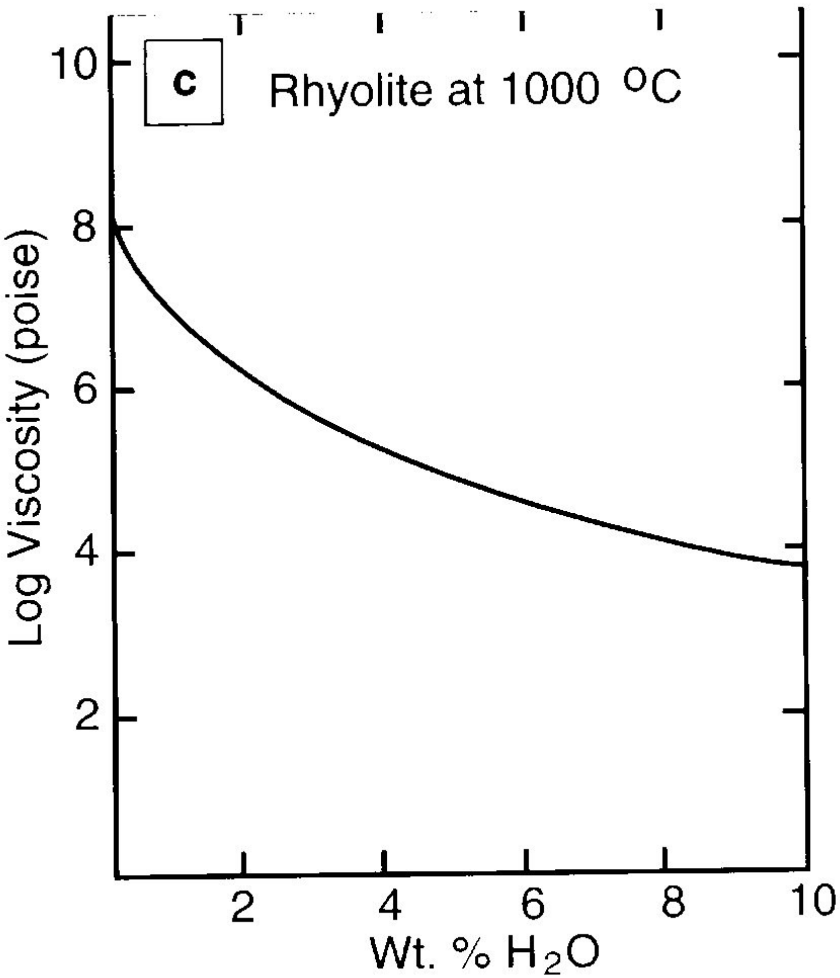
Announcements

- **Reading: p.120-127; p.293-304; p.316-318**
- **Download HW 1 from web: due April 17**
- **Field trip 1 is definitely April 29-30**

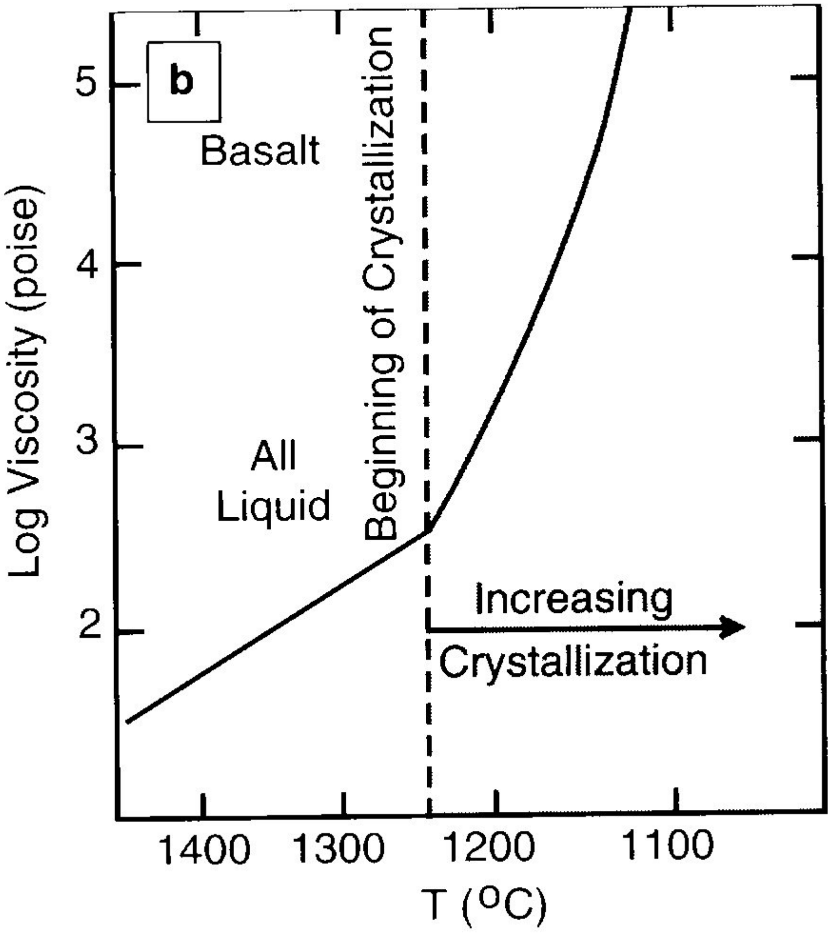
Water: effect on viscosity





Water, bubbles, crystals

- Water lowers viscosity
- Also causes crystallization at lower T: increases viscosity
  - (demo 2)
- Bubbles form- increases viscosity



Important Ideas

- Silicate melts have open structures and local ordering
  - can accommodate many volatiles, large cations, noble gases
- Typical densities: 2.2-3.1 g/cm^3
- Typical viscosities
  - 500-1,000,000 poise
- Water, bubbles, crystallization, and T all affect melt viscosity

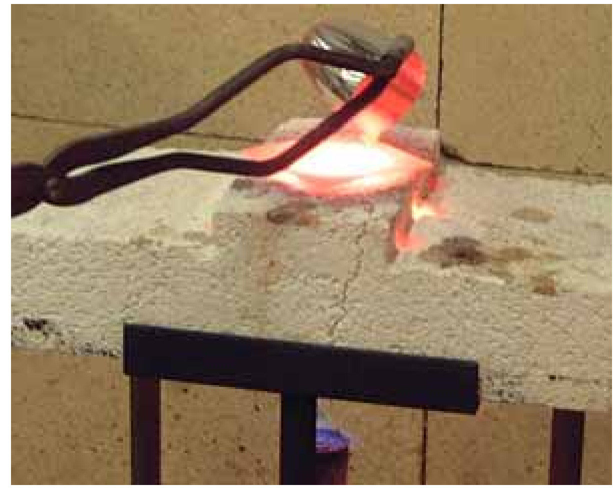
How do we measure and record composition?

- Bulk composition: want to know composition of original melt
- Bulk composition is easier to measure on some samples than on others (example)

Measurement of bulk composition 1. chemical composition

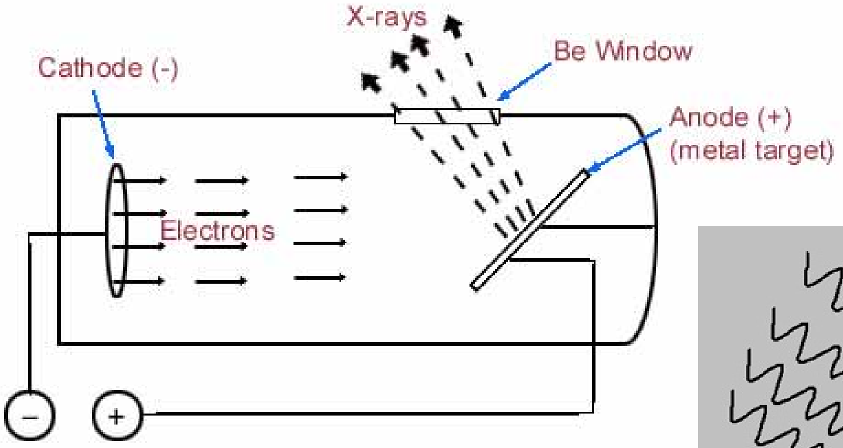
- Most common analysis until 60’s
- Wet chemistry: dissolve rock in acids
- Precipitate oxides of each cation and weigh material

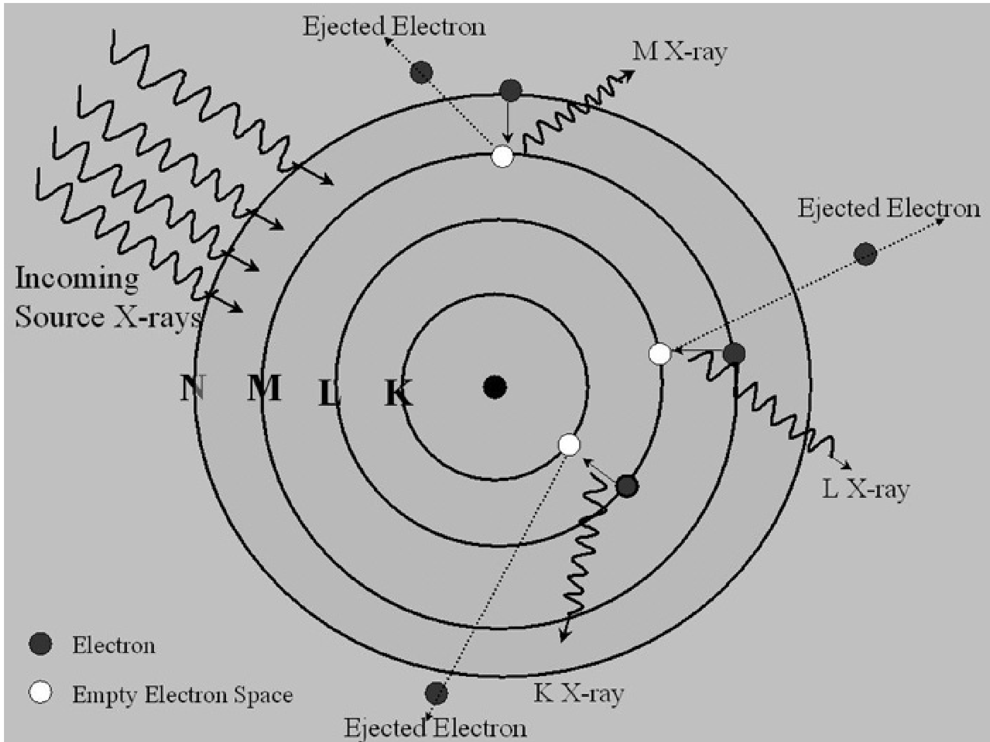
Bulk composition with XRF: sample preparation



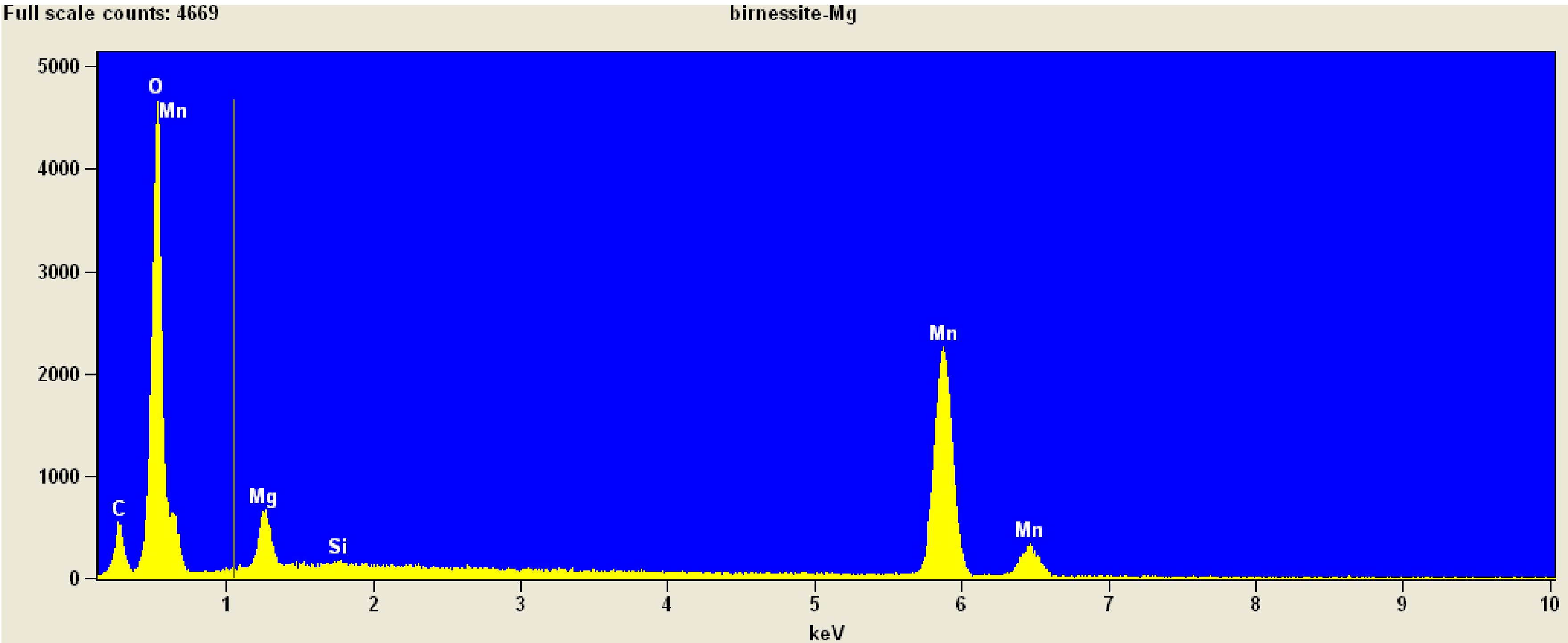
Or just press a pellet…

XRF: principles of technique





XRF: principles of technique



Use this to quantify # atoms of each element: then convert to oxides!

Other bulk measurement methods mentioned in text?

Results: convert everything to wt% oxides!

Table 8-3. Chemical analyses of some representative igneous rocks

	Peridotite	Basalt	Andesite	Rhyolite	Phonolite
SiO_2	42.26	49.20	57.94	72.82	56.19
TiO_2	0.63	1.84	0.87	0.28	0.62
Al_2O_3	4.23	15.74	17.02	13.27	19.04
Fe_2O_3	3.61	3.79	3.27	1.48	2.79
FeO	6.58	7.13	4.04	1.11	2.03
MnO	0.41	0.20	0.14	0.06	0.17
MgO	31.24	6.73	3.33	0.39	1.07
CaO	5.05	9.47	6.79	1.14	2.72
Na_2O	0.49	2.91	3.48	3.55	7.79
K_2O	0.34	1.10	1.62	4.30	5.24
H_2O^+	3.91	0.95	0.83	1.10	1.57
Total	98.75	99.06	99.3	99.50	99.23

Major elements: usually greater than 1%

SiO_2 Al_2O_3 FeO* MgO CaO Na_2O K_2O H_2O

Minor elements: usually 0.1 - 1%

TiO_2 MnO P_2O_5 CO_2

Trace elements: usually < 0.1%

everything else

Conversion of units

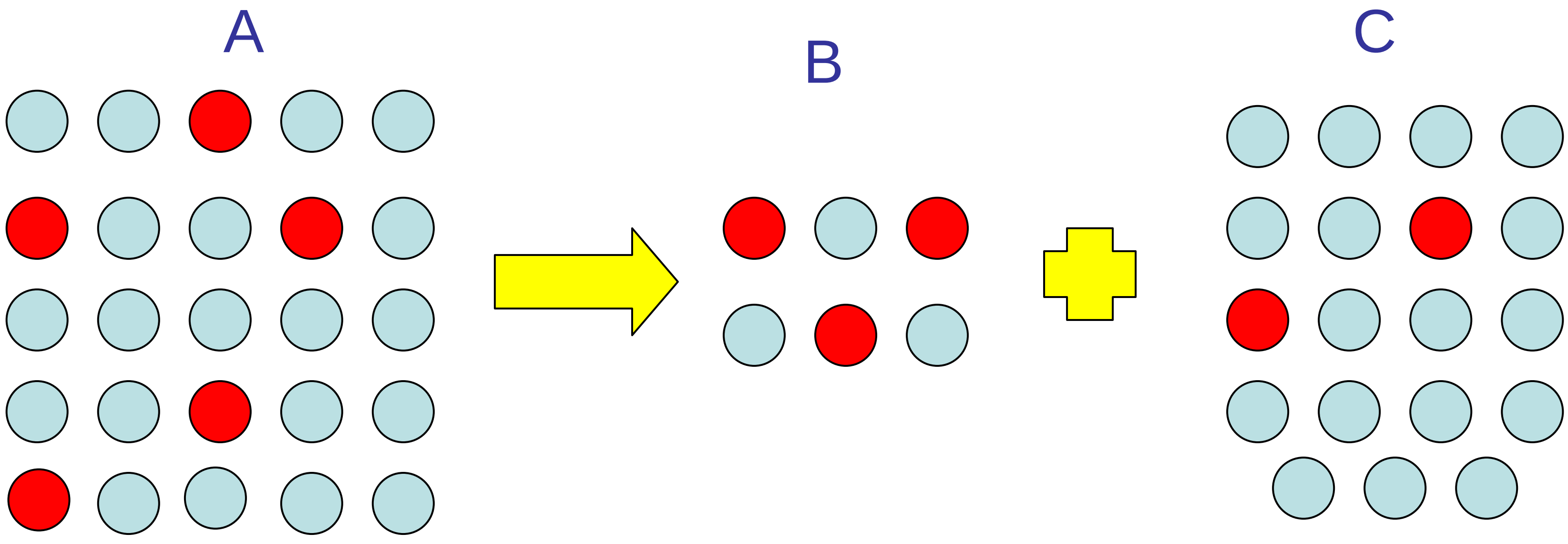
- How to convert wt% oxides to mol?

Table 8-1. Chemical Analysis of a Basalt (Mid-Atlantic Ridge)

Oxide	Wt. %	Mol Wt.	Atom Prop.	Atom %
SiO_2	49.2	60.09	0.82	17.21
TiO_2	2.03	79.88	0.03	0.53
Al_2O_3	16.1	101.96	0.32	6.64
Fe_2O_3	2.72	159.70	0.03	0.72
FeO	7.77	71.85	0.11	2.27
MnO	0.18	70.94	0.00	0.05
MgO	6.44	40.31	0.16	3.36
CaO	10.5	56.08	0.19	3.93
Na_2O	3.01	61.98	0.10	2.04
K_2O	0.14	94.20	0.00	0.06
P_2O_5	0.23	141.94	0.00	0.07
H_2O^+	0.70	18.02	0.08	1.63
H_2O^-	0.95	18.02	0.11	2.22
(O)			2.82	59.27
Total	99.92		4.76	100.00
	ppm			ppm
Ba	5	137.33	0.04	0.8
Co	32	58.93	0.54	11.4
Cr	220	52.00	4.23	88.9
Ni	87	58.70	1.48	31.1
Pb	1	207.20	0.01	0.1
Rb	1	85.47	0.01	0.3
Sr	190	87.62	2.17	45.6
Th	0	232.04	0.00	0.0
U	0	238.03	0.00	0.0
V	280	50.94	5.50	115.5
Zr	160	91.22	1.75	36.9

Data from Carmichael *et al.* (1974), p. 376, col. 1

Mass balance: bean-counting



$[X] = 5/25 = 0.2$ $[X] = 3/6 = 0.5$ $[X] = 2/19 = 0.11$

$$A[X]_A = B\,[X]_B + C[X]_C$$

Geochemists count beans all the time!

Measurement of bulk composition 2. mineralogy

- Mode is the volume % of minerals seen
- Norm is a calculated "idealized" mineralogy based on a set protocol for assigning oxides to mineral species "CIPW Norm"

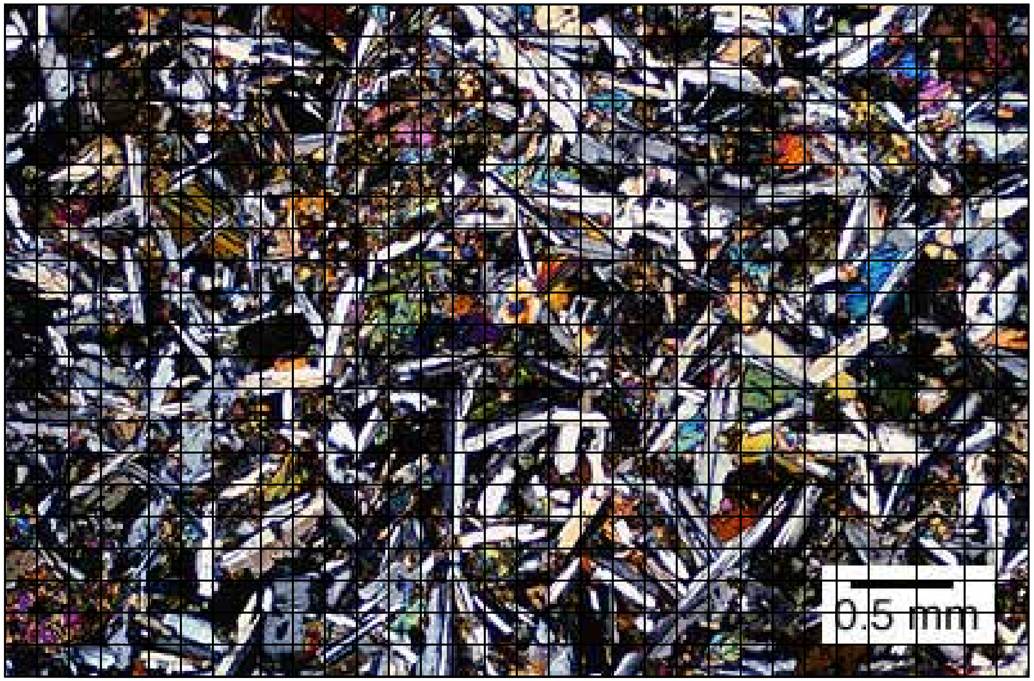
	Fo	En	Q
SiO_2	42.7	59.9	100
MgO	57.3	40.1	

Measurement of bulk composition

- Point counting of thin sections: modal abundance

Looks like fun?

Mode = norm ?



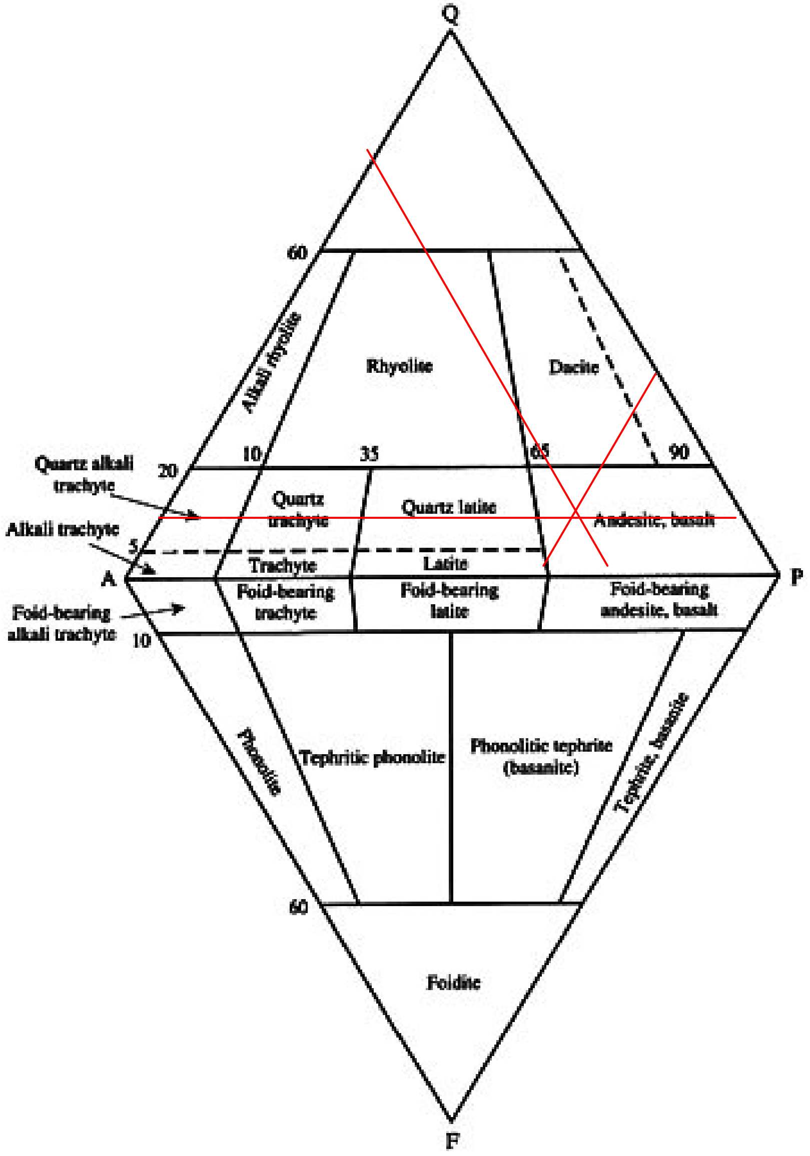
Naming igneous rocks

- Nomenclature out of control
  - How to effectively communicate correct information to others?
- In 60's and 70's IUGS made standard charts to determine igneous rock names

Adakite	**Andesite**	**Basalt**	**Camptonite**	Comendite
Adamellite	Ankaramite	**Basanite**	Cancalite	Cortlandite
Alaskite	**Anorthosite**	**Beforsite**	**Carbonatite**	
Alnöite	Aplite	**Benmoreite**	Cedricite	
Alvekite		**Boninite**	Charnockite	

Examples of determining nomenclature

1. Volcanic rock or plutonic?
2. Normative mineralogies (modal)
   1. Q = quartz
   2. A = alkali feldspar
   3. F = feldspathoids
   4. M = mafic minerals



Example: Q 5% A 15% P 30%

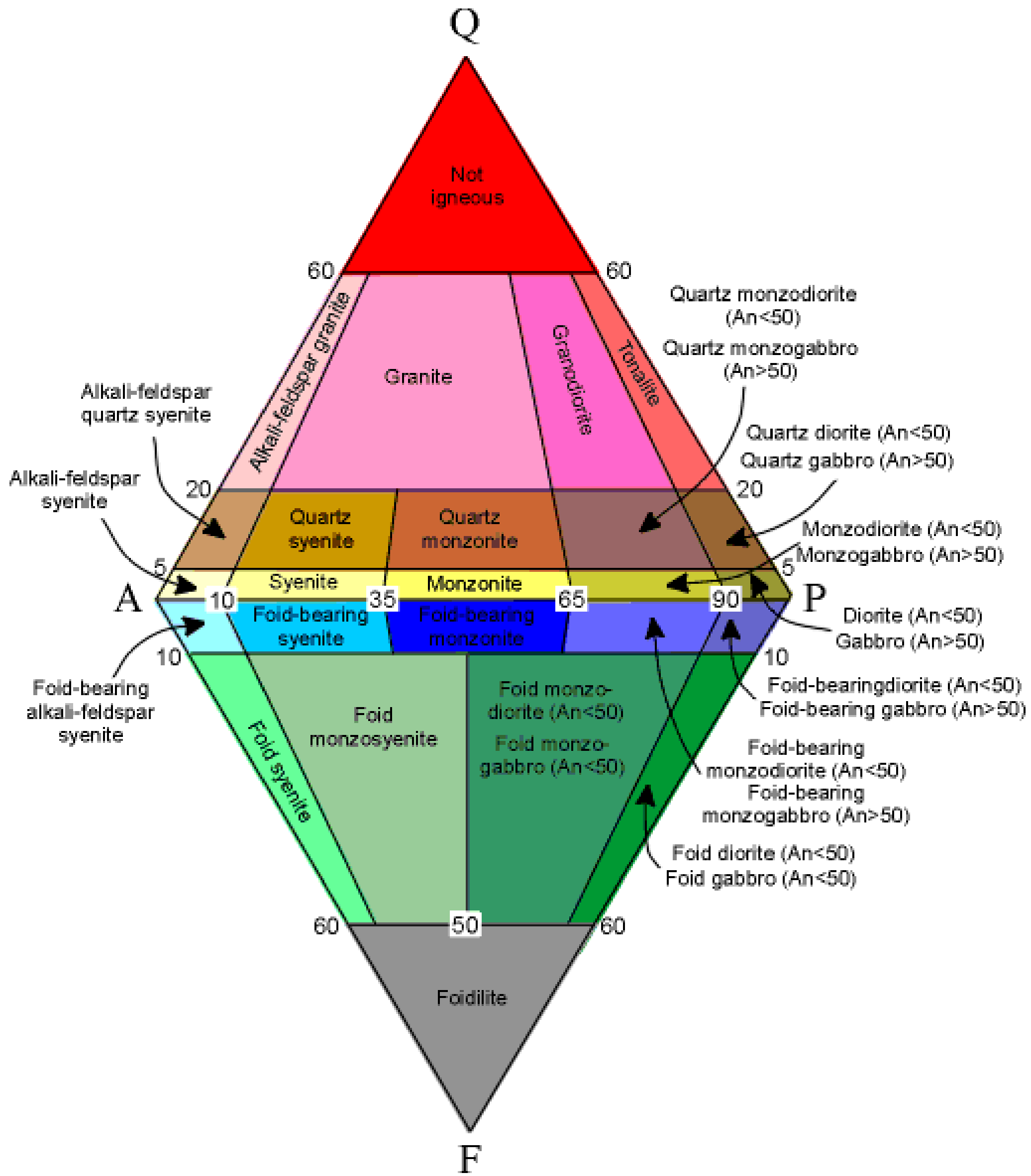
Examples of determining nomenclature

- Intrusive: separate modal plots

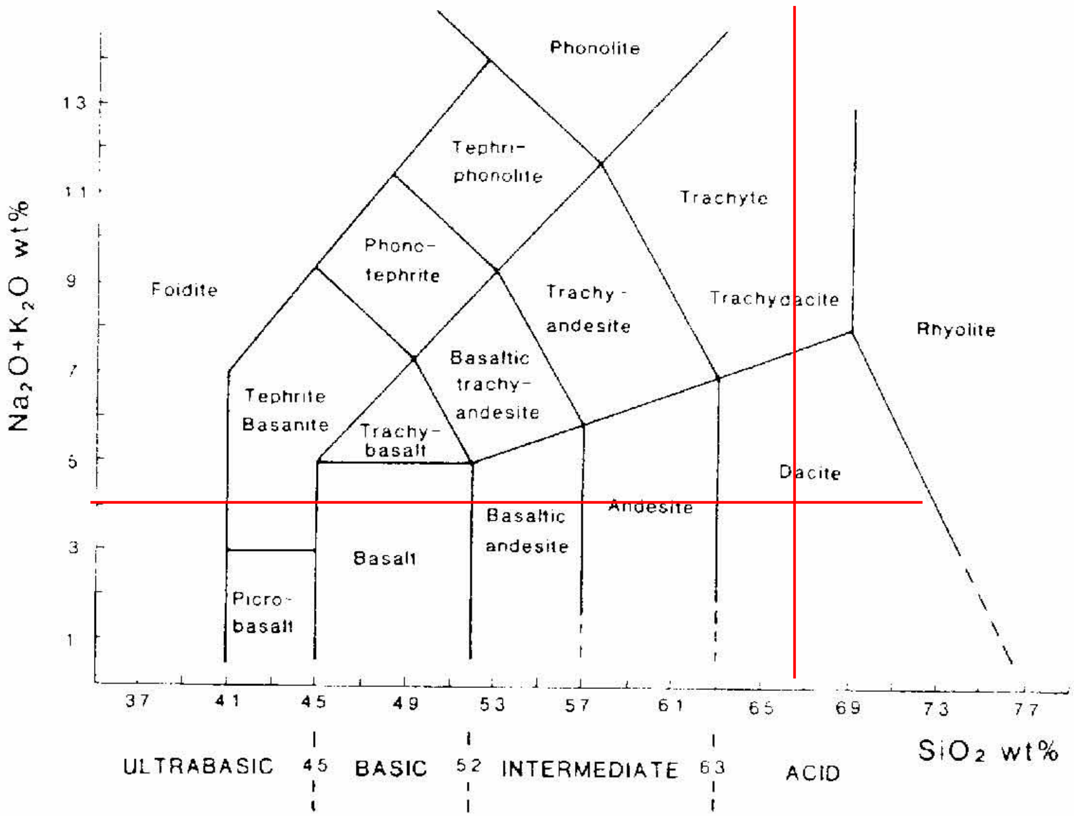
Include modifiers, if appropriate:

“Biotite granite”

“Hypidiomorphic quartz syenite”



Volcanic rock: chemical composition



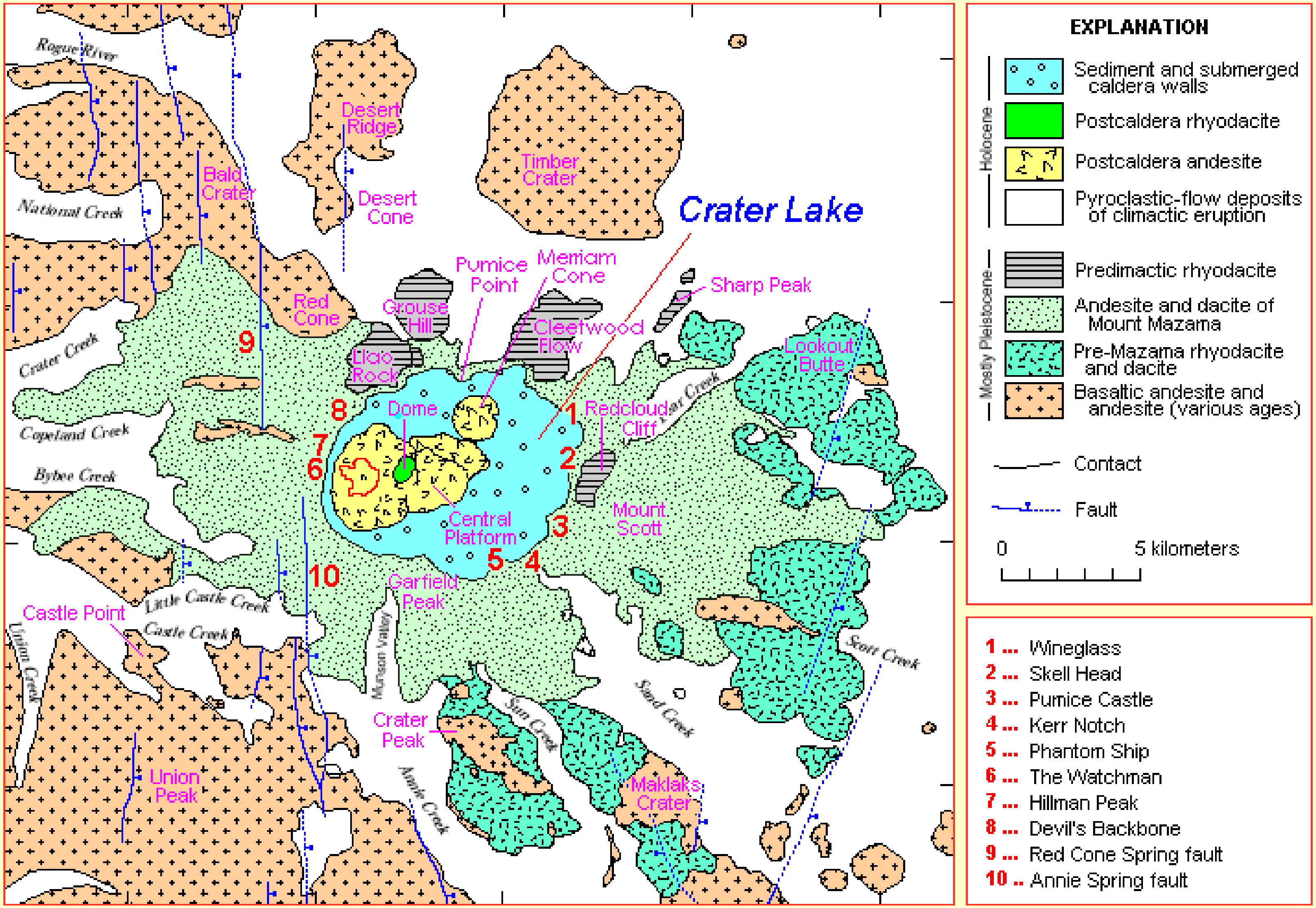
More nomenclature

- Peraluminous A>CNK
- Metaluminous CNK>A>NK
- Peralkaline NK>A
  - A,C,N,K are molecular amounts of Al_2O_3, CaO, Na_2O, K_2O
- Silica saturation and undersaturation: figure 8-12

Crater Lake, OR

Eruption 7000 years b.p. reduced 12000 ft (3700 m) tall mountain to caldera about 6100 ft above sea level

Generalized Geologic Map of Mount Mazama and Vicinity



USGS

Topinka, USGS/CVO, 2001; Modified from: Bacon, et.al., 1997, USGS Open-File Report 97-487;
Map Data Source: C. R. Bacon, unpublished mapping, 1996; some features from: U. S. National Park Service Map

Harker diagrams
for Crater Lake

What features do you observe in these diagrams?

(X, Y, data clusters)

Primitive vs. evolved magmas

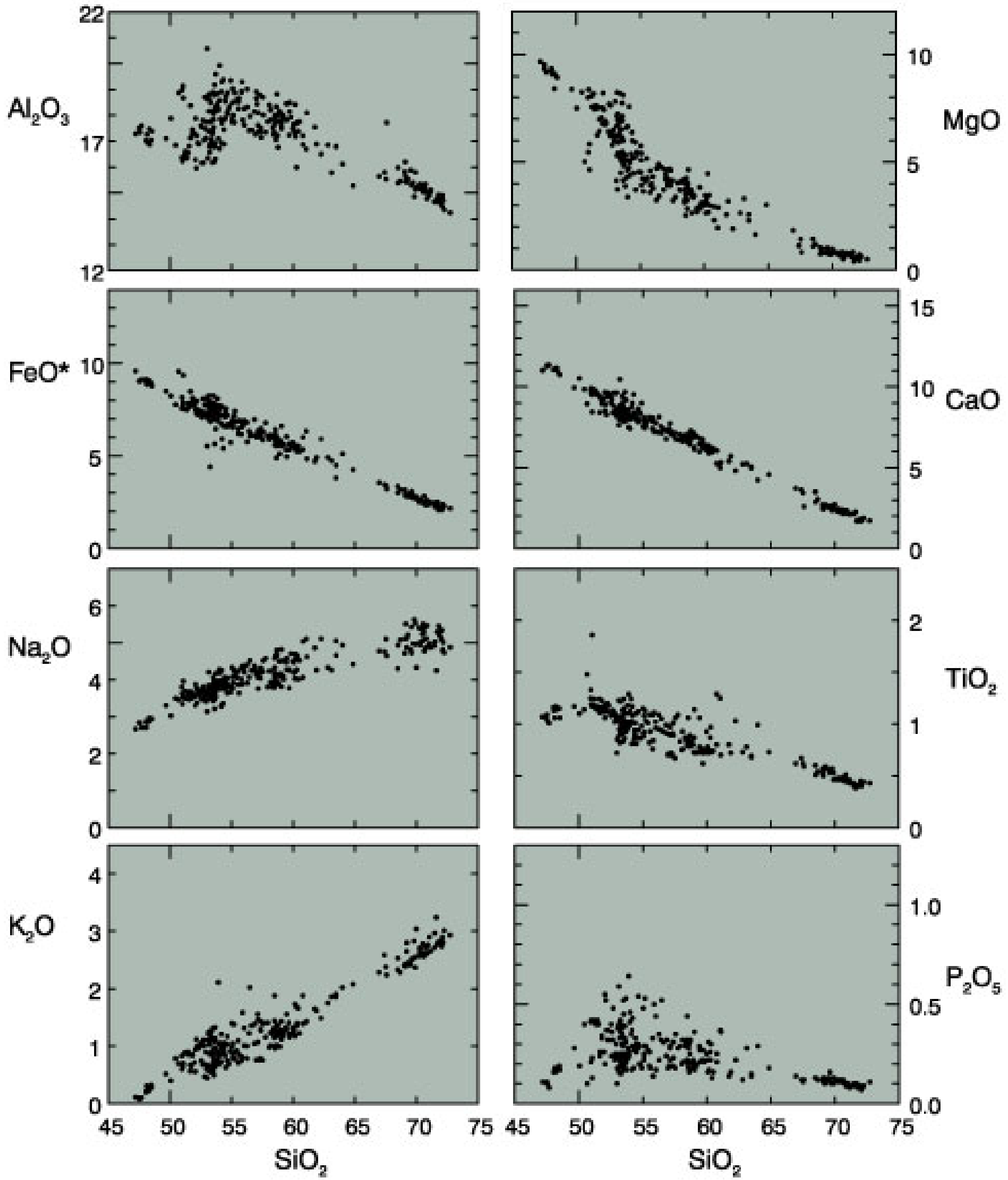
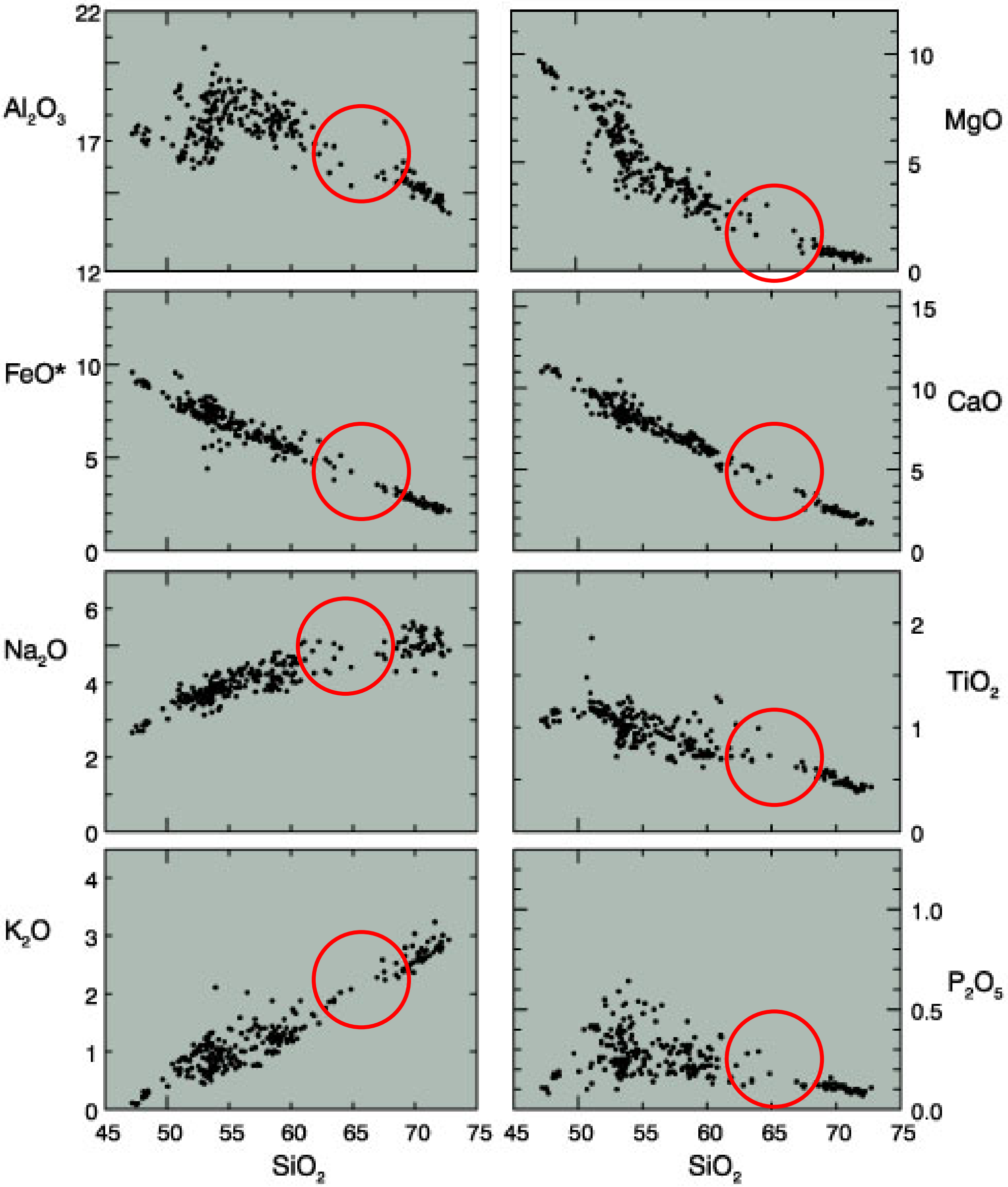


Figure 8-2. Harker variation diagram for 310 analyzed volcanic rocks from Crater Lake (Mt. Mazama), Oregon Cascades. Data compiled by Rick Conrey (personal communication).

The Daly Gap

- Fractional crystallization?
- Partal magma mixing?
- Oxide crystallization?



Harker diagram for Crater Lake

Describe trends qualitatively with fractional crystallization

- Trends = liquid line of descent
- The most primitive lava on the diagram is the parent magma
- What phases typically crystallize from magmas?
- Adjust % of remaining components (Na, K)

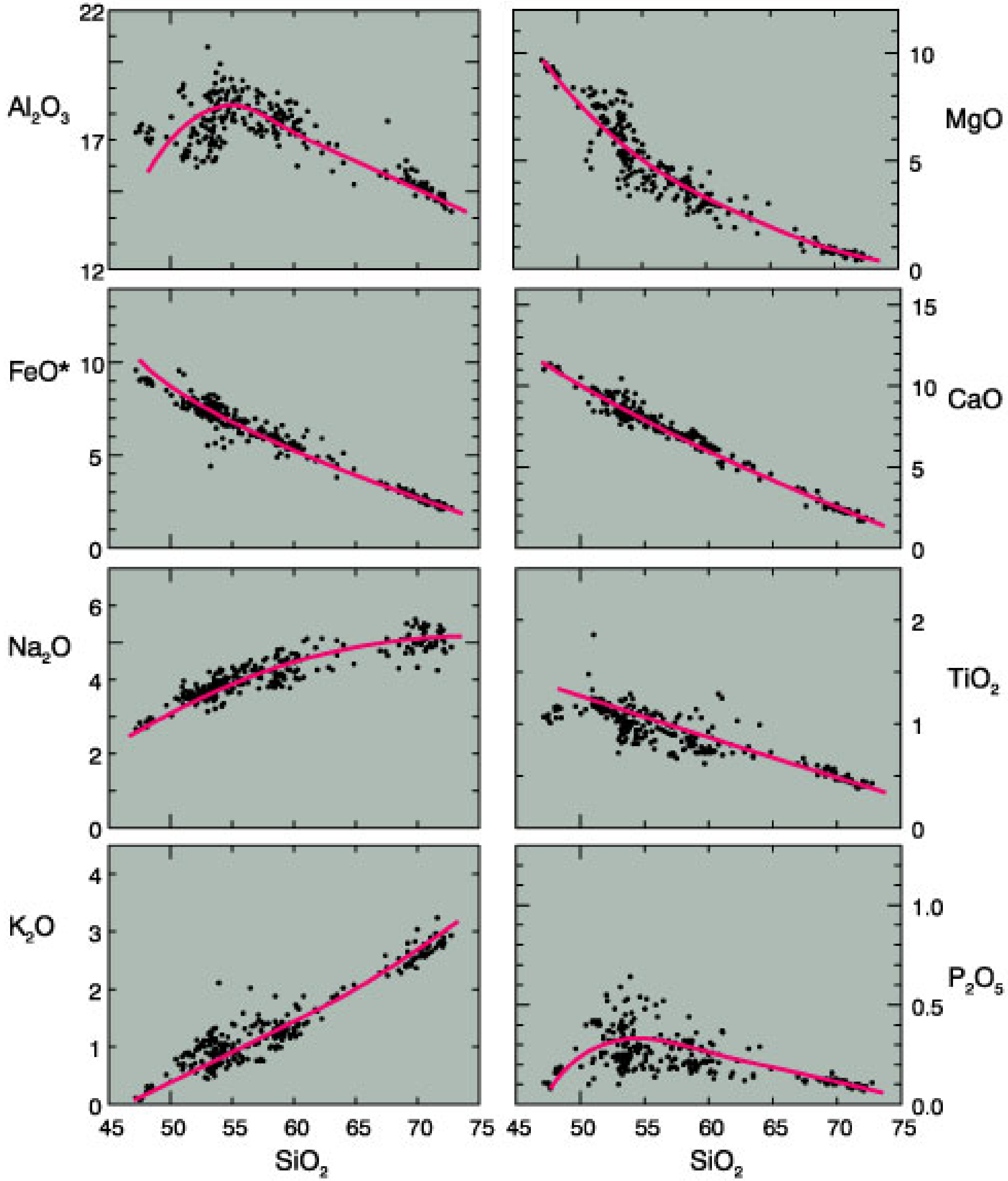


Figure 8-2. Harker variation diagram for 310 analyzed volcanic rocks from Crater Lake (Mt. Mazama), Oregon Cascades. Data compiled by Rick Conrey (personal communication).

Summary of important points

- Rock compositions are generally expressed in wt% oxides for historical reasons
- Conversion between units
- Mode vs. norm
- IUGS diagrams and other chemical composition diagrams allow us to have a standard nomenclature
- Harker diagrams