EARTH AND SPACE SCIENCES 212

LAB 1: VOLCANIC ROCKS (4 hours)

Compositions, mineral assemblages, textures, classification and occurrence

The purpose of this lab is to acquaint you with a range of common volcanic rock types and their associations. By association, we refer to a particular geologic (tectonic) setting where certain types of volcanic rocks typically occur together, e.g., the *basalt—andesite—dacite—rhyolite* association of convergent continental margins. It will become apparent that the same type of rock, e.g. basalt, may be found in more than one tectonic environment. What distinguishes these different basalts may be the style of their eruption (visible only in the field), or subtle **petrographic** features (best observed in thin section) or **chemical** differences (verifiable only by chemical analysis). You will also discover that volcanic rocks with similar chemical compositions can have different textures due to different styles of eruption and different volatile contents. For example, a **dacite** could occur as an *aphanitic lava flow*, *a porphyritic flow*, *a sill, a dike*, *a welded tuff, an unwelded tuff* (loosely consolidated pumice fragments, glass shards and crystals).

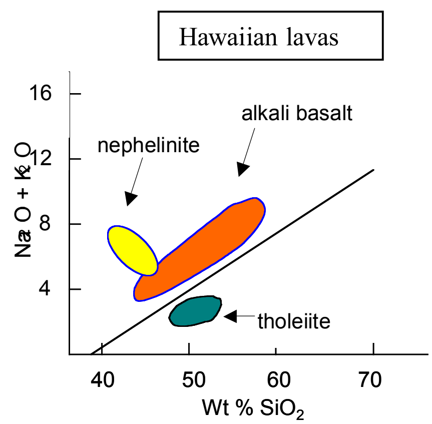
Volcanic Rock Classification:

There are several igneous rock classifications in existence, each of which has some merit. Most geologists, however, prefer to adopt a relatively simple classification scheme sufficient to permit meaningful communication. It should be emphasized that all schemes are to some extent arbitrary and that igneous rock compositions are gradational and do not always fit nicely into prescribed pigeonholes. There are basically **two** ways to classify igneous rocks using [a] ***mineralogical*** data or [b] ***chemical*** data. Secondary criteria that are sometimes used are ***textures, mode of occurrence, or tectonic environment***, e.g., the term "mid-ocean ridge basalt (MORB)" is clearly using the criterion of tectonic environment to distinguish these basalts from chemically and mineralogically similar basalts in other tectonic settings, for example "OIB (ocean island basalt)" or "CFB (continental flood basalt)". In addition, the subdivision of igneous rocks into ***volcanic*** and ***plutonic*** groups is dependent on mode of occurrence and textures.

The most widely used classification scheme is that proposed by the **IUGS** (International Union of GeoScientists) which is based on the **MODE** of the rock, i.e., ***the volume percent of the constituent minerals***. Details on this classification scheme will be provided in the lecture material posted on the class website There are separate **IUGS** classification schemes for [a] volcanic rocks, [b] silicic plutonic rocks (quartz-bearing), and [c] ultramafic and mafic plutonic rocks (quartz-free). We will use the IUGS system for plutonic rocks because it is usually possible to determine modes in these relatively coarse-grained plutonic rocks. However, since we only have hand sample descriptions in this class, we will use simpler classification procedure (outlined below) for volcanic rocks which are aphanitic, or in some cases, glassy. Because volcanic rocks are fine-grained and/or glassy, modes are difficult or impossible to determine if one only has hand samples available. A simple classification of volcanic rocks based mainly on the phenocryst assemblage will be used in this class (see below).

For more precise work, classification of volcanic rocks is based on chemical data. The normal procedure in chemical classification is to compute the chemical analysis in terms of ***normative minerals*** (**NORM**). Normative minerals are a set of carefully chosen mineral compositions that are calculated from the chemical analysis following a set of prescribed rules. The rationale is that the normative minerals would closely mimic the actual minerals, both in type and relative abundance, if the rocks had cooled slowly in a plutonic environment. This is only partly correct since the norm calculation does not include hydrous minerals such as amphiboles or micas. A classification based on the norm is of limited use in this class or in the field since the only data we have are hand sample petrographic observations.

In the absence of thin section information we will use a classification scheme for common volcanic rocks based on the color of the sample and the phenocryst assemblage with the understanding that it is less than ideal.



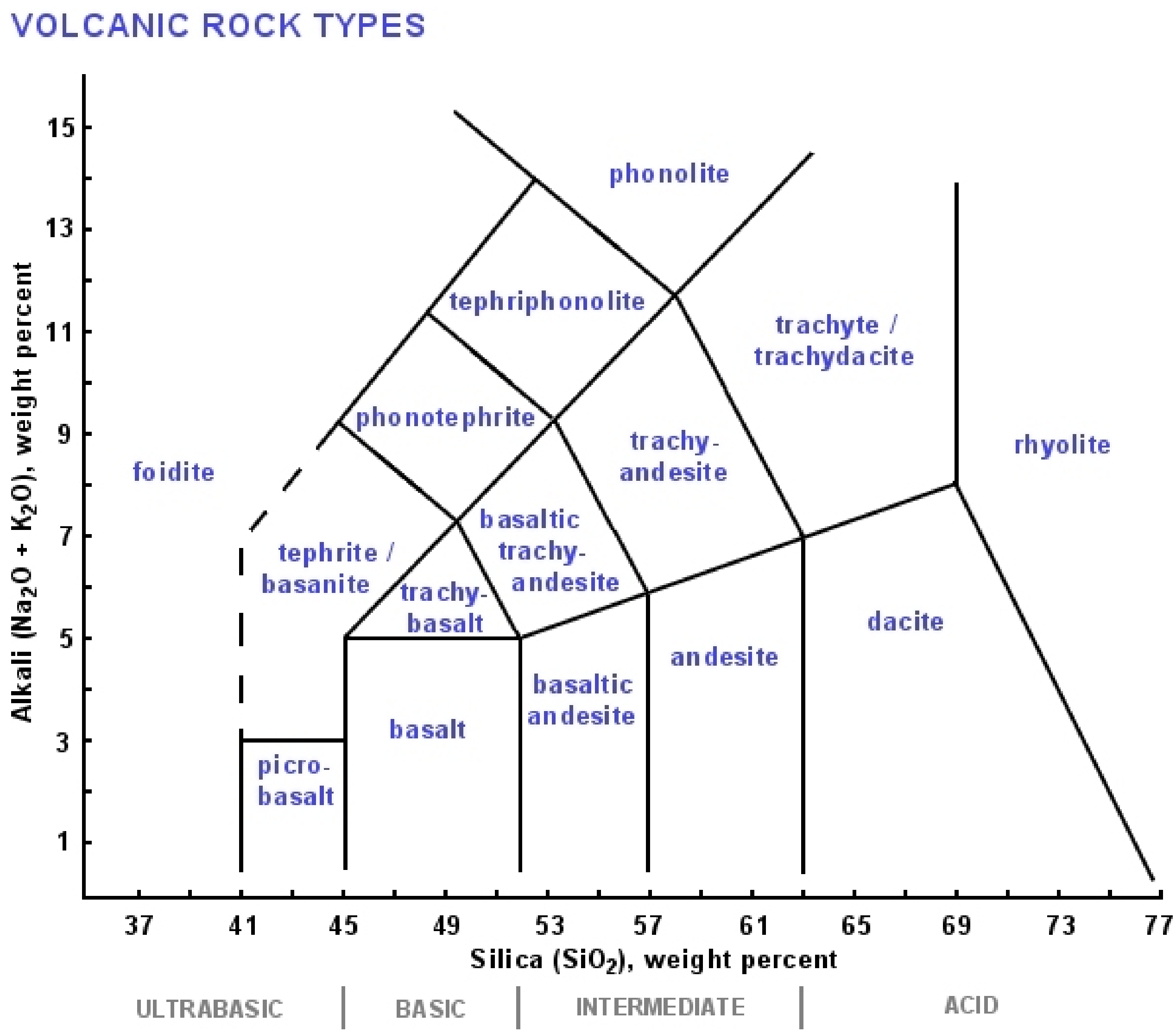
Basalts: Dark-colored, fine-grained rock, commonly porphyritic with phenocrysts of olivine and/or plagioclase and less commonly clinopyroxene. In some coarser-grained basalt hand samples it may be possible to identify groundmass minerals (predominantly plagioclase and clinopyroxene). There are two main classes of basalt (a) tholeiite and (b) alkali basalt. These are very difficult to distinguish without chemical analysis of thin sections and we won't attempt to distinguish them in the labs. The simplest way to distinguish them is to plot total alkalis ($Na_2O + K_2O$) against SiO_2.

Andesite: Usually grey in color, commonly porphyritic with phenocrysts of plagioclase and pyroxene (orthopyroxene and/or clinopyroxene) and/or hornblende. Groundmass may be aphanitic or glassy.

Dacite: Relatively light-colored, commonly porphyritic with phenocrysts of plagioclase along with relatively minor amounts of phenocrysts of quartz and sanidine and even smaller amounts of mafic phenocrysts (hornblende, biotite) set in a fine-grained or glassy matrix. Commonly occur as pyroclastic flows (tuffs).

Rhyolite: Light-colored rock which may be totally glassy (obsidian), or may contain phenocryts of plagioclase, quartz and sanidine in a glassy or very fine-grained matrix. Mafic phenocrysts are rare. Many rhyolites occur as pyroclastic rocks (ash flow tuffs or ignimbrites) showing varying degrees of welding and compaction. Pumice (highly vesicular glass) fragments are rounded in non-welded tuffs and flattened and less vesicular in welded tuffs.

Many other volcanic rocks exist but thin sections and/or chemical analysis are necessary to classify them accurately. A simple, but widely used, chemical classification of volcanic rocks based only on the alkalis ($Na_2O + K_2O$) and SiO_2 contents is below.



Volcanic Rock textures

In this lab you will be introduced to some common textural terms applied to volcanic rocks. There are many more textural terms than those listed below; however, most of these are of limited use and can be omitted at this point. It is not necessary to memorize all the textural terms during the first lab--you will have the opportunity during the rest of the quarter to familiarize yourselves with the various terms.

TEXTURE refers to the ***size***, ***shape***, ***arrangement*** **and** ***mutual relations*** of crystalline grains (and glassy material) in rocks. Texture is primarily a function of magma composition, crystal nucleation rate, crystal growth rate, and cooling rate.

FABRIC is a related term used when discussing preferred orientation of minerals [fabric may or may not be visible in the outcrop or hand sample and may require detailed microscopic measurements.]

STRUCTURE refers to clearly **mesoscopic** features such as jointing, flow banding, mineral layering, pillows, etc., which may develop independent of the texture.

CRYSTALLINITY: the following terms relate, in general terms, the relative volume percentage of the crystalline and non-crystalline material [glass] in a rock.

HOLOCRYSTALLINE: entirely crystalline, e.g., all plutonic rocks
HYPOCRYSTALLINE: partly crystalline and partly glassy, e.g., many volcanic rocks
HOLOHYALINE: entirely glassy, e.g., obsidian

GRAIN SIZE:

FINE-GRAINED: Grain diameter < 1mm
MEDIUM-GRAINED: Grain diameter between 1 and 5 mm
COARSE-GRAINED: Grain diameter >5mm
PHANERITIC: Crystals are visible to the naked eye;
APHANITIC: Crystals are not visible to the naked eye;
PEGMATITIC: crystals are extremely large.

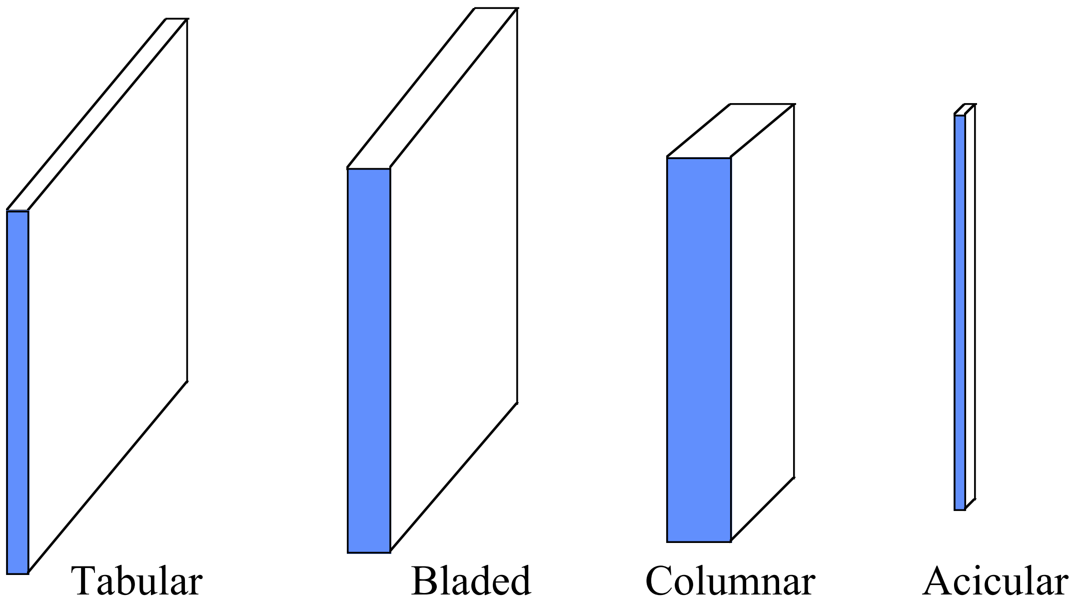
CRYSTAL FORMS:

EUHEDRAL: crystals with fully developed crystal faces
SUBHEDRAL: crystals showing partial development of crystal faces
ANHEDRAL: no development of crystal faces.

GRAIN SHAPES [crystal habits]

The terms *EQUANT, TABULAR, PRISMATIC, ACICULAR* (needle-like), *FIBROUS, SKELETAL* are self-explanatory terms commonly used to characterize the 3-dimensional shape of crystals in a rock. Some examples are illustrated below.

Crystal Shapes



TEXTURAL TERMS [used to describe the ***overall texture*** of a volcanic rock]

PORPHYRITIC: an inequigranular texture characterized by the presence of **phenocrysts**, i.e., mineral of *conspicuously* larger grain size than those of the **groundmass or matrix** which may be crystalline or glassy. A rock with phenocrysts in a glass matrix is called a **vitrophyre**. Note that porphyritic does not imply anything about absolute crystal sizes.

**SERIATE PORPHYRITIC*: phenocrysts occur in continuous range of sizes down to the size of the crystals in the groundmass.
**HIATAL PORPHYRITIC*: discontinuity in the range of crystal sizes.
POIKILITIC*: numerous inclusions of one mineral within another. The host mineral is referred to as an **oikocryst and the included mineral is a **chadacryst.**
**INTERSERTAL*: glass fills the interstices between plagioclase crystals, a common texture in some basalt.
**OPHITIC*: A special type of a poikilitic texture in which large grains of pyroxene enclose smaller plagioclase grains. A common texture in some basalts and diabases.

*Terms marked by asterisk are most easily seen in thin sections. If time permits, we will demonstrate these and set up some thin sections on microscopes on the back bench.

TRACHYTIC: a texture [due to flow] in which feldspar grains are oriented subparallel and are enclosed within a finer grained matrix.
SPHERULITIC: spherical aggregates of radial microcrystals [commonly alkali feldspar and a silica polymorph]. Spherulites commonly form during the devitrification of obsidians.

EUTAXITIC: a texture common in welded ash flow tuffs (ignimbrites) in which fragments of glass (shards) and pumice (fiamme) tend to be flattened and deformed by compaction.

VESICULAR: bubble-like cavity in a volcanic rock caused by the escape of gas. **Pumice** is a frothy vesicular obsidian; **scoria** is a highly vesicular basalt. An **amygdule** is a vesicle filled with secondary minerals. **Pipe vesicles** are tube-like, elongated vesicles.

***LITHOPHYSAE (best seen in the field)*: cavities common within ash-flow deposits and some rhyolite lava flows, e.g., Obsidian Cliffs in Yellowstone Park. Formed by entrapment of vapors. These cavities are often lined by crystals precipitating out of the vapor phase.

***MIAROLITIC (best seen in the field)*: a crystal-lined cavity in granite, e.g., Golden Horn batholith in the North Cascades National Park presumably formed where gases escaping from the cooling magma were trapped. These cavities commonly contain beautifully faceted rare minerals.