Chapter 1

THE FELDSPARS

Feldspars are an important group of minerals, because they constitute more 50% of the Earth crust. From the crystallographic point of view, both natural and synthetic feldspars show a wide span of typology respect to very simple chemical compositions. In fact, feldspars group can be summarized as solid solution of the following pure terms:

Potassic feldspar	$K(AlSi_3O_8)$	Or
Sodic feldspar	$Na(AlSi_3O_8)$	Ab
Calcic feldspar	$Ca(Al_2Si_2O_8)$	An
Baric feldspar	$Ba(Al_2Si_2O_8)$	Cn

All feldspars are tectosilicates constitute by a tetrahedral framework $(Si,Al)O_8$. When an Al^{3+} has substituted one Si^{4+}, neutrality of the structure is guaranteed by K^+ or Na^+ ions. In the same way, when Al^{3+} substitute two $Si^{4+,}$ the electrostatic charge is balanced by a bivalent cations as Ca^{2+}. In plagioclase structure the relative amount of tetrahedral Al varies as function of relative quantity of Ca^{2+} e Na^+. This framework can be schematized as double interconnected chains called “double goose neck”. The best compatible symmetry with this framework is that of the spatial monoclinic group C2/M, which is the symmetry of feldspars with disordered of Si and Al inside the tetrahedral. However, in the majority of feldspars, the real symmetry is less, due to the following causes:

1. Disordered distribution of Si and Al inside the tetrahedral;
2. Collapse of the cavities filled by extra tetrahedral cations, smaller than the cavity volume.

The factor 1 induces in the framework with ratio Si:Al=3:1 an *Albite Type* order, which reduce the symmetry from monoclinic C2/m to triclinic C1. The same factor, in feldspars with ratio Si:Al=1:1 in the framework, generates an *Anorthite Type* order, reducing the symmetry from C2/m to I2/c. Factor 2 produces a collapse in the alum-silicate framework, inducing or a symmetry reduction or a deviation different from the typical 90° of α and γ angles of the triclinic cell.

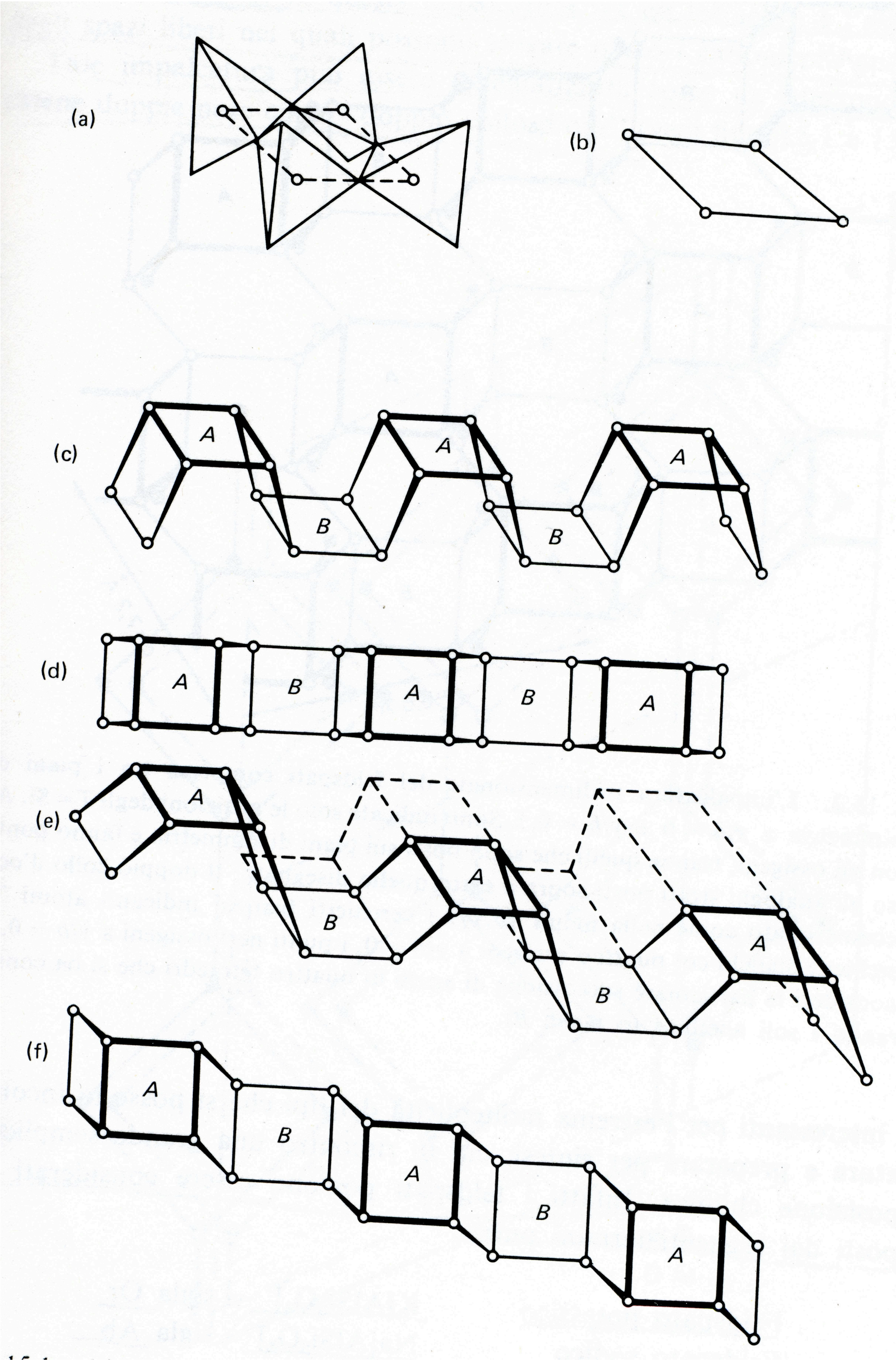


Fig. 1.1 a) T_4O_{12} ring of four tetrahedral TO_4; **b)** Schematic representation of the same ring; **c)** succession of ring composed of four tetrahedral called "double goose neck"; **d)** Orthogonal view of the double goose neck structure; **e)** Deformed double goose neck; **f)** Orthogonal view, deformed double goose neck.

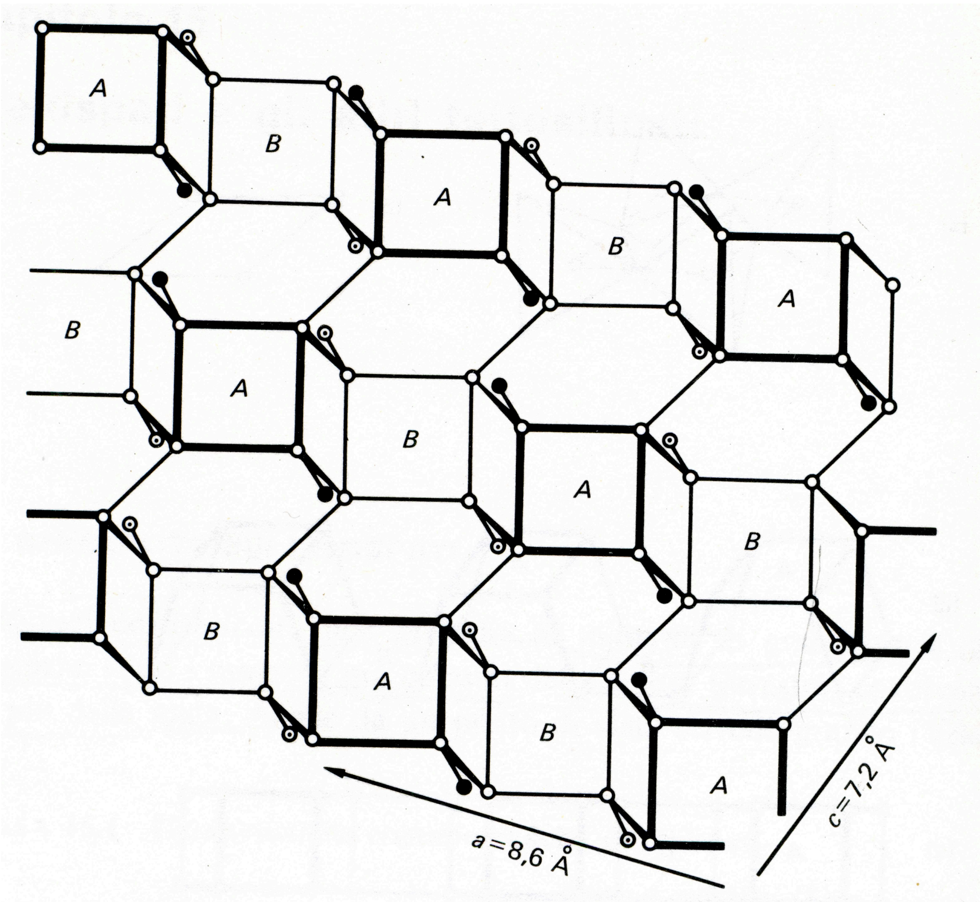


Fig. 1.2 tridimensional framework of feldspars between the plane of symmetry a y/b=0 e Y/b=0,5. White circles are atoms T, white circles with black points are oxygens at y/b=0 and black points are oxygens at y/b=5.

1.1 The Ab-An system: the plagioclases

The Ab-An system, commonly called plagioclases, is a typical example of complete isomorphism. Plagioclases are very frequent in natural rocks, and have been classified on the base of compositional variations as follow:

From	$Ab_{100}An_{0}$	to	$Ab_{90}An_{10}$	Albite
From	$Ab_{90}An_{10}$	to	$Ab_{70}An_{30}$	Oligoclase
From	$Ab_{70}An_{30}$	to	$Ab_{50}An_{50}$	Andesine
From	$Ab_{30}An_{70}$	to	$Ab_{10}An_{90}$	Bytownite
From	$Ab_{10}An_{90}$	to	$Ab_{0}An_{90}$	Anorthite

An Order-Disorder polymorphism exists, a high-temperature and a low-temperature series have been proposed. A complete miscibility exists at high temperature as evident in the crystallization diagram in (Fig. 1.3).

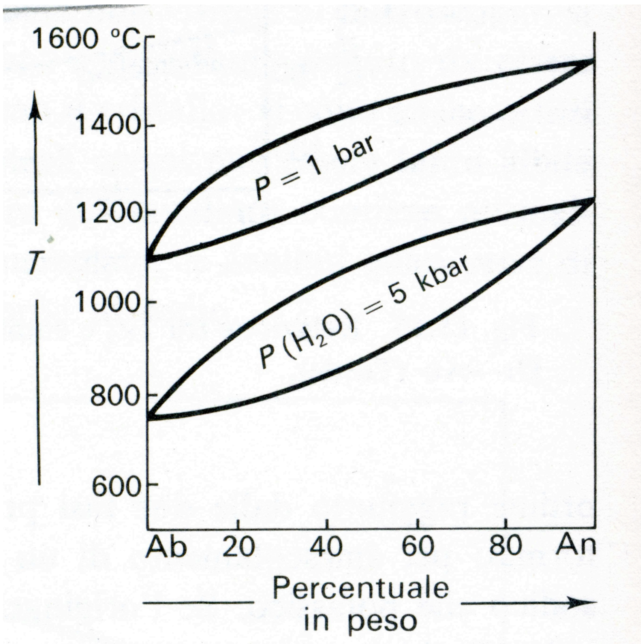


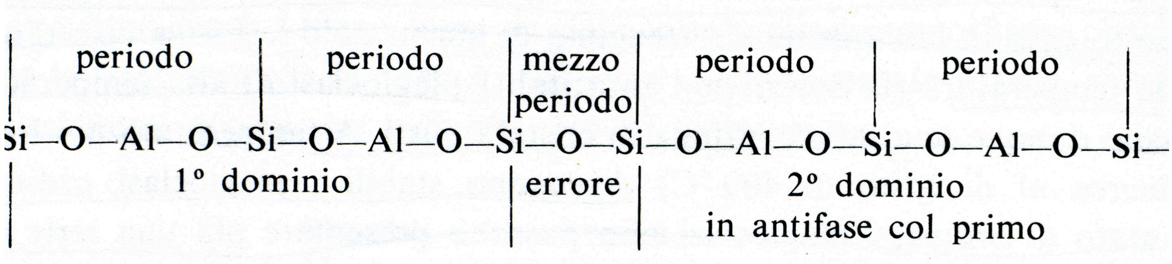
Fig. 1.3 Plagioclase crystallization diagram at atmospheric pressure (Bowen) and at PH_2O (Yoder, Stewert and Smith)

In a similar binary system, phenocrysts enriched in the most refractory component, in this case the anorthite (An) crystallizes first. For this reason, natural plagioclase is often zoned, characterized by a calcic core followed by a series of progressively more albitic overgrowth. However, this normal zonation is quite rare and plagioclases often present inverse zoning and compositional variations due to changing in physical growth conditions.

At lower temperature (~400°C) more ordered plagioclases are stabilized. In the ordered state, plagioclases cannot have a complete isomorphic series. In tectosilicates Al-O-Al bond cannot exist, in some cases it is possible to substitute Al with Si in the anorthite structure, but in any case, it is not permitted to substitute any Si with Al in albite framework, without create "forbidden" Al-O-Al bonds. On the basis of these observation Chao & Taylor (1940) proposed a model of alternating albitic and anorthitic domains for ordered plagioclases.

1. Plagioclases from $Ab_{100}An_0$-$Ab_{95}An_5$ have albite type structure;
2. Plagioclases from $Ab_{25}An_{75}$-Ab_0An_{100} have anorthite type structure;
3. Plagioclases with composition $Ab_{85}An_{15}$-$Ab_{25}An_{75}$, presents antiphase anorthitic domains.

To better explain what anorthitic antiphase domain is, it is useful to remember that the order in tectosilicates derive from alternating of Si and Al and, if an error occurs, and between tetrahedral the common Si-O-Al it is substituted by a Si-O-Si bond, the following atoms will be arranged in a similar domain but in "antiphase" and shifted by an half period, as illustrated in the following scheme:



1.2 The system Or-Ab-An

The system Or-Ab-An can be schematized in a triangular diagram, as those in Fig. 1.4 cotectic line divides the triangle; on this line two feldspars crystallize contemporaneously. For compositions corresponding to point below the line, plagioclase (Ab-An) start to crystallize, and residual melt composition move toward the cotectic line; when reach it, eutectic crystallization occur. Otherwise, if initial composition of the melt is above the eutectic line, K-feldspars initially crystallize.

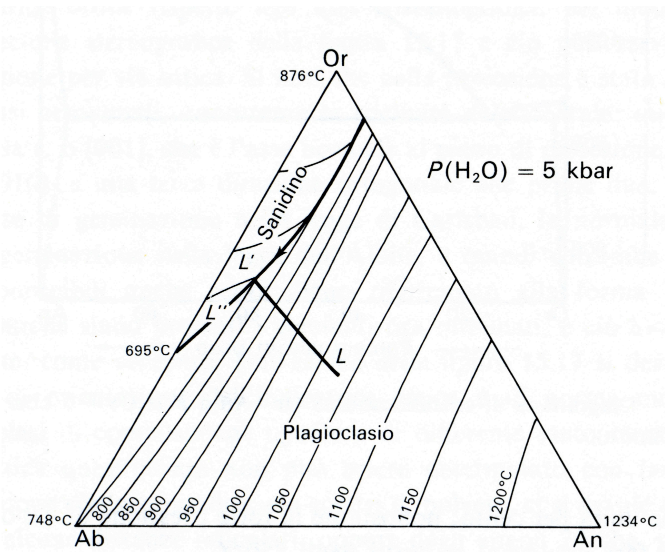


Fig. 1.4 Ternary crystallization diagram of Or-Ab-An at PH_2O (From Yoder, Stewart and Smith).

Plagioclase crystallization proceed as complete miscible solid solution, first crystals are enriched in most refractory phase (An). These crystals should react with the melt to generate crystals in equilibrium with the melt, but this rarely occurs due to the low interdiffusion of Si-Ca and Al-Na in the solid. As consequence crystals become zoned, characterized by a calcic core followed by several overgrowths, progressively enriched in Ab.