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DEPARTMENT OF GEOLOGY

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ANORTHOSITES

The term anorthosite, from French ‘anorthose’ (term for plagioclase) was coined by Sterry Hunt. They are leucocratic coarse-grained plutonic rocks consisting essentially of plagioclase (usually labradorite or bytownite) often with small amounts of pyroxene. Olivine, amphibole, ilmenite, magnetite, and spinel are also sometimes present.

Anorthosite are not particularly abundant on Earth. As a rock type, it can be stated that anorthosites have formed over the entire range of geological time, and presumably are still forming today.

Classification

Anorthosite occurrences are quite diverse, and when their distinctive features are used to categorize them, it becomes apparent that some types show very clear temporal restrictions.

Ashwal (1993) listed six major types or anorthosite occurrences:

1. Archean anorthosite plutons
2. Proterozoic “massif-type” anorthosite plutons
3. Anorthosites of layered mafic intrusions
4. Anorthosites in oceanic setting
5. Small inclusions in other rock types (xenoliths and cognate inclusions)
6. Lunar anorthosites

1. Archean megacrystic anorthosites

   Archean anorthositic rocks can be found as a minor component of many, but not all Archean greenstone belts, where they are associated with mafic intrusive and extrusive rocks. Where preserved, their primary textures are distinctive, being characterized by equidimensional megacrysts (up to 30 cm diameter) of calcic (usually > An80) plagioclase in a mafic groundmass. A genetic connection between this type of anorthosite and the mafic volcanic rocks of greenstone belts is implied by occurrences of basaltic flows, sills and dikes that contain similar megacrysts of calcic plagioclase, and from the chemical similarities between the basalts and the mafic groundmass surrounding the megacrysts in some anorthosites.

2. Proterozoic (massif-type) anorthosites

   This type is the most abundant of terrestrial anorthosites, occurring as small plutons to batholith-sized composite intrusive complexes up to 15.000-20.000 km2. Some of these larger complexes can be shown to consist of 20 or more individual coalescent plutons. Plagioclase is intermediate in composition (typically An40 or An-60) and occurs as lath-shaped crystals; in some cases, such crystals may reach 1 m across. In addition to intermediate plagioclase, the associated primary minerals of massif-type anorthosite include pyroxene, olivine (or both), Fe-Ti oxides and apatite. Thus age, composition and magmatic texture distinguish Proterozoic massif-type from Archean megacrystic anorthosites.

3. Anorthosites of layered mafic complexes

   Layered mafic intrusions range in age from Archean to Tertiary, and commonly contain anorthosites in varying proportions. Commonly, anorthosites form at the tops of modally graded layers on the scale of several meters up to 100 meters or more. Grain size (typically <1 cm) is characteristically smaller than the massif-type or Archean anorthosites, and textures vary from orthocumulates with tabular crysts of plagioclase to adcumulates having equant polygonal grains.

4. Anorthosites of oceanic settings

   Small amounts of anorthosite have been recovered by dredging programs in both mid-oceanic ridge and fracture-zone settings, especially in the Caribbean Sea and the Atlantic and Indian oceans. Ophiolitic anorthosites commonly occur as sharply bounded layers as of those in Layered mafic intrusions. The ages of formation of anorthosite-bearing ophiolite complexes range from late Cambrian to early Eocene.

5. Anorthosite inclusions in other rock types

   Anorthosites also occur as inclusions in other igneous rocks ranging in composition from kimberlite to basalt to granite. Some can be demonstrated to be xenolithic, and represent fragments of other anorthosite types incorporated into ascending magmas. Others, however, are cognate, and represent accumulations of plagioclase from their host magmas.

6. Lunar anorthosites

   Samples returned by the Apollo 11 landing on the moon included some brecciated anorthosites. The landing area was on Mare Tranquilitatis, and the maria are known to be basaltic. The composition of lunar anorthosite plagioclase is very anorthitic (An94–99). The anorthosites contain abundant Si, Ca, and Al, with some Na and Fe, but little else. The low Na and K contents may reflect an early loss of alkalis in the moon. The anorthosites are also very old: 4.4 Ga.

Petrogenesis

Anorthosites are cumulates of plagioclase feldspar from mantle-derived basaltic magmas. The favored model for (terrestrial) anorthosite petrogenesis involves a mantle plume (head?) that induces peridotite melting in the spinel– or plagioclase–herzolite stability field. The resulting aluminous basaltic liquid rises and ponds at the base of the crust. The heated crust melts to produce granitic liquids, leaving a hot plagioclase– pyroxene–rich granulite residue that is readily assimilated by the basaltic liquids. Whether mantle or crustal melts predominate at this stage is debated. Crystal fractionation produces olivine and pyroxene, which sink, and plagioclase, which floats. The upper plagioclase-rich crystal–liquid mush rises in several pulses to shallower levels, and the dense Fe-rich interstitial liquid is expelled downward, leaving adcumulus masses of anorthosite. Anorthosites, constituting the lunar highlands rose and crystallized either from a thick magma layer that encircled the entire moon or did so from a series of intermittent melting events.

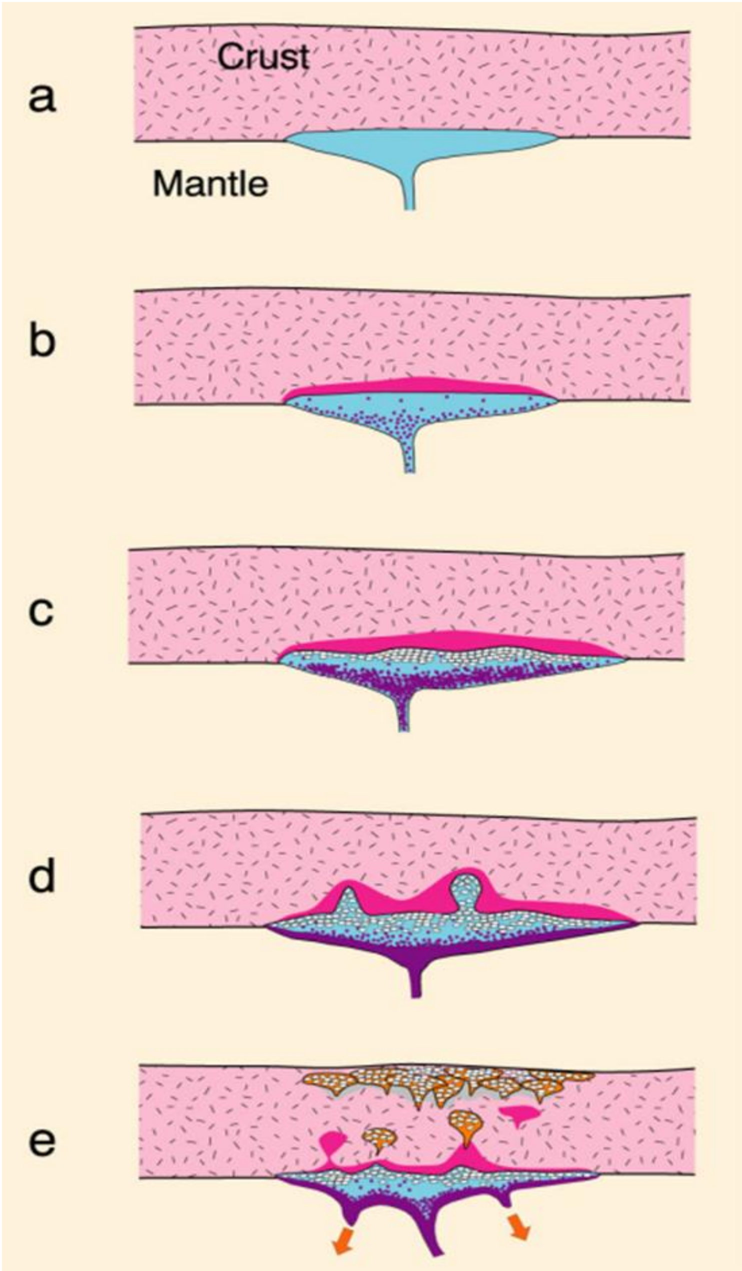

Figure 1- Model for the generation of Massif-type anorthosites. a) Mantle-derived magma underplates the crust as it becomes density equilibrated. b) Crystallization of mafic phases (which sink), and partial melting of the crust above the ponded magma. The melt becomes enriched in Al and Fe/Mg. c) Plagioclase forms when the melt is sufficiently enriched. Plagioclase rises to the top of the chamber whereas mafics sink. d) Plagioclase accumulations become less dense than the crust above and rise as crystal mush plutons.e) Plagioclase plutons coalesce to form massif anorthosite, whereas granitoid crustal melts rise to shallow levels as well. Mafic cumulates remain at depth or detach and sink into the mantle. [From Ashwall (1993)]