

The origin of some ultramafic rocks: a preliminary survey of the evidence for and against gravitative accumulation of olivine.

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Evidence generally considered favourable to the hypothesis.

General evidence.

- (a) No aphanitic representatives.
- (b) No olivine-basalt is found to contain more than a moderate amount of olivine without having the excess amount present as phenocrysts.
- (c) Little or no thermal metamorphism of adjacent rocks or xenoliths.
- (d) Concentration of olivine phenocrysts in the lower parts of lava flows or flow units.
- (e) Evidence of sinking in the upper parts of the Kilauean magma column.
- (f) Scattering of point on variation diagrams which have the amount of Si or SiO_2 as the main co-ordinate of reference.
- (g) Consideration of relative specific gravity and low viscosity.

Evidence from the minor intrusions in Skye.

- (a) Relatively wide dikes and sheets.
- (b) Relatively more olivine in wider dikes.
- (c) Types extremely rich in olivine are very localised in occurrence.
- (d) Variation in amount of olivine in individual dikes and sheets.
- (e) Examples with about 80 % of idiomorphic olivine.
- (f) Partial cataclasis of olivines or splitting along cleavages.
- (g) These intrusions are commonly xenolithic.
- (h) Chilling at margins is confined to groundmass which is basaltic.
- (i) Phenocrysts of olivine are found in these contact selvages.
- (j) No evidence of a large content of volatiles.

Evidence from thick sills.

- (a) Olivine-rich layer near the base of the Palisades diabase. Olivine-rich to olivine-free gradation postulated without significant change in the chemical composition of the olivine.

- (b) Picrite near the floor of the main Shiant Isles sill and in the lower part of some sills in northern Skye. Ultramafic-mafic gradation postulated in certain cases. Original magma, where found as a contact selvage, was basaltic (crinanitic).
- (c) Ultramafic zones in the Lugar sill. Magma or magmas were rich in alkalies and volatiles. Gravitational settling of olivine postulated but not in situ. Upper contact selvage is teschenitic but bulk composition of the sill is considerably more mafic.

Evidence from large layered intrusions (Skaergaard, Bushveld, Stillwater, etc.).

- (a) Ultramafic-mafic gradations within the layers.
- (b) Actual or inferred occurrence of ultramafic rocks towards the base of such intrusions.
- (c) Original magma (chilled marginal or floor phase) was basaltic.

Experimental Evidence.

- (a) High melting point and high temperature of crystallisation of Mg-olivine in Mg_2SiO_4 - Fe_2SiO_4 system.
- (b) High temperature of crystallisation of Mg-olivine in MgO - FeO - SiO_2 system.
- (c) No dunitic liquid formed below $1000^\circ C.$ and under high pressure in MgO - SiO_2 - H_2O system.
- (d) Gravitational settling of olivine crystallised in an artificial melt.
- (e) Gravitational settling of partially melted olivine in a melted basalt.

Comments on some evidence which is apparently unfavourable to the hypothesis.

General evidence.

- (a) The existence of large masses of igneous rock which are vertically homogeneous through hundreds of feet.
- (b) High specific tendency of olivine to crystallise.

Evidence from lavas.

- (a) Over 10,000 feet of picrite-basalts at the base of the Tertiary lava succession of Ubekendt Ejland, West Greenland.
- (b) Spectacular development of zeolites in flow units or flow banding in these picrite-basalts. The olivine is commonly fresh and there is no evidence of violently explosive activity. The zeolites are regarded as original magmatic components. There is very little tuff. What is possibly the approximately contemporaneous horizon on the mainland, is characterised by breccias, both olivine-rich and zeolite rich in some localities.
- (c) Close chemical equivalence of porphyritic alkaline olivine-rich basalts to aphanitic nepheline-basalts.
- (d) Composition of the aphanitic groundmass of olivine-fourchite was determined by Fenner as ultramafic.

- (e) Even distribution of olivines *and* augites in ankaramites.
- (f) Very little evidence of size-sorting of olivines.
- (g) During the 1931 eruption on the island of Réunion the oceanite (picrite-basalt) lava flowed and glowed like a very fluid, hot basaltic magma.

Evidence from both lavas and minor intrusions.

- (a) Crystals of olivine, which are more typically developed in picrite-basalt lavas than in intrusions, might be interpreted in many cases as microlitic or skeletal rather than corroded crystals. Many of these crystals would have been disintegrated during eruption and flow of the lavas had they been formed and accumulated at an earlier period. Such crystals suggest rapid crystallisation from a supersaturated solution.
- (b) Evidence of a large initial content of volatiles in many cases.
- (c) Recent field and laboratory examination of the main Shiant Isles sill has revealed a sharp junction, in all exposed localities, between the picrite and olivine-dolerite. This sill is one of the most widely quoted examples of ultramafic-mafic gradation.
- (d) The ultramafic components of certain other sills could not have been formed by gravitative settling of olivine in situ. Yet columnar jointing may stretch without break or change from top to bottom. This evidence suggests a uniformly operative cooling throughout such sills as exhibit it. Similar columnar jointing is also continuous throughout the main sill of the Shiant Isles.

Experimental Evidence.

- (a) The specific tendency of olivine to crystallise is so great that it has not been found possible so far to obtain a uniform glass from a melted picrite-basalt from Ubekendt Ejland. Microlites of olivine form too readily.

Conclusions.

Effective removal of constituents of zeolitic composition with concomitant concentration of an ultramafic residuum is tentatively suggested as an alternative explanation which appears more applicable in a number of cases. No attempt is yet made to explain the mechanism of this possible removal. The main object has been to draw attention to evidence. To explain certain aspects of this evidence by accumulation of olivine seems too facile and inadequate.

Ultramafic rocks *may* be formed, at least partly and indirectly, as residues as well as accumulations, the olivine crystallising essentially in situ.

This survey of the problem will have served a useful purpose if it establishes only a reasonably well-founded doubt that the concept of olivine accumulation may not be so widely applicable a solution — as many petrologists previously believed — to the origin of the ultramafic rocks associated with tholeiitic, crinanitic or teschenitic magma.