

*Solubility of basalt under atmospheric conditions of
temperature and pressure*

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Summary. Simple laboratory experiments involving the contact of distilled water with crushed olivine-basalt over several months under atmospheric temperature and pressure conditions have shown that constituents are dissolved from the basalt and upon evaporation the solutions deposit crystals of carbonates, smectites, and zeolites. The results bear out the observations and conclusions previously made in the field that solutions depositing secondary minerals in Tertiary basalts in New South Wales are extraneous and cold. It is also suggested that as the assemblage calcite–montmorillonite–heulandite can form in the vesicles of basalts under such conditions it should not be included in the zeolite facies of metamorphism.

IN an investigation of the nature of the infillings of vesicles in a basalt (Nashar and Davies, 1960), it was observed that some of the minerals were of relatively recent formation and that deposition of minerals appeared to be still going on.

The present investigation is an endeavour to determine the processes involved in the formation and transport of these secondary minerals and their deposition in the vesicles. This involves two assumptions: that the secondary minerals are formed from the constituents of the basalt at ambient temperature and pressure, and that the rock, as a whole, is sufficiently porous to absorb and permit the movement of water and aqueous solutions within the texture of the rock.

The porosity of the basalt has been demonstrated qualitatively by first removing all adsorbed air from the surface of a flake of the rock and then subjecting it to reduced pressure while immersed in air-free water. A stream of minute air-bubbles emerged from several places on the flake. No attempt was made to measure the porosity at this stage but its existence was quite evident.

In order to test the solubility of olivine basalt in cold distilled water at room temperature and pressure and the nature and composition of the solute and solutions, the following simple experiments were carried out on a fresh olivine basalt from near Tubrabucca Hut, Hunter's Springs, Barrington Tops, New South Wales.

The olivine basalt consists of phenocrysts of olivine set in a very fine grained groundmass of labradorite ($Ab_{38} An_{62}$) laths and augite granules; the olivine is partly serpentinized; the plagioclase laths show fluidal fabric; ilmenite granules are widespread and many are altered to leucoxene. Abundant interstitial chlorite occurs throughout the rock. A chemical analysis of the rock gave: SiO_2 44.20%, Al_2O_3 16.20, Fe_2O_3 3.40, FeO 7.90, MgO 11.10, CaO 9.65, Na_2O 3.05, K_2O 1.00, TiO_2 1.60, P_2O_5 0.55, MnO 0.26, loss on ignition 1.80, total 100.71%.

TABLE I. Compositions of solutions obtained by the action of cold water on olivine basalt. Compositions in parts per million

	Total solids	SiO_2	CaO	$(Al,Fe)_2O_3$	P_2O_5	Na_2O	MgO
Expt. 1	54.00	7.00	9.00	2.30	0.73	6.50	6.35
Expt. 2	76.00	13.50	10.60	1.30	tr.	7.20	n.d.*

* Insufficient material.

Experiment 1. A sample of basalt was crushed to -20 mesh. 400 g of the crushed rock were agitated with 4 l. of distilled water at 25° C for 100 hours after which the solution was allowed to stand for 24 hours to clear. An analysis of this solution is given in table I.

The solution was then evaporated in vacuo, the temperature at no time rising above 30–35° C. After about 3.5 l. of water had been evaporated the first appearance of solute was observed. This solute consisted of brown-coloured isotropic material (n 1.57). At this stage the evaporation in vacuum was stopped and the remaining solution was allowed to evaporate slowly under atmospheric temperature and pressure in an endeavour to obtain crystals of the solute. The final product was a fine white powder which, under the microscope, was seen to be composed of tiny (0.005 mm) globule-like crystals of calcite embedded in a colourless medium (n approx. 1.49), which under crossed nicols showed crystallization to an aggregate of low-doubly-refracting material.

Experiment 2. The crushed basalt from experiment 1 was again agitated intermittently with another 4 l. of distilled water for six months. An analysis of this solution is given in table I.

The higher 'total solids' in the second solution may possibly be attributed to the longer period of contact of water with the basalt and hence the decomposition of some of the primary minerals by hydrolysis.

In an attempt to obtain crystals, 1.5 l. of the second solution were evaporated and nine fractions of solute as they successively crystallized were collected and examined periodically over two months:

1. Minute (0.01 mm) globule and dumb-bell-shaped crystals of calcite and a few pieces of montmorillonite–nontronite as hexagonal-shaped brown, zoned plates and lath-shaped longitudinal sections showing second order interference colours and n 1.57 to 1.58, embedded in a fawn-coloured isotropic matrix (n 1.49).

2. Brown mineral (montmorillonite–nontronite) more abundant than in (1); very little calcite; zeolite (?) with straight extinction and first-order-grey interference colours and green to pale brown-coloured nebulous-shaped masses crystallizing from the isotropic matrix.

3. Minute (0.005 mm) rhomb-shaped crystals of carbonate (not calcite) with low interference colours, n approx. 1.56, length fast along longer diagonal, effervesces in HCl, possibly vaterite (CaCO_3).

4. Calcite and montmorillonite–nontronite in the isotropic matrix.

5 and 6. Colourless isotropic matrix with minute crystals of montmorillonite–nontronite, calcite, and laths of zeolite (possibly heulandite) up to 0.02 mm long recognized by grey interference colours, length slow, extinction angle 0–12°.

7. Almost perfect colourless crystals up to 2 mm long of lansfordite ($\text{MgCO}_3 \cdot 5\text{H}_2\text{O}$).

8. Radiating tufts of acicular nesquehonite ($\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$) and single crystals of lansfordite.

9. Radiating nesquehonite crystals and zeolite, which is beginning to crystallize out of the matrix. Zeolite is possibly heulandite with n 1.488, grey mottled interference colours, length slow.

The minute grain size and mixed nature of the specimens rendered identification of the components most difficult. X-ray identification was of little assistance because the patterns were not distinct and were mixtures. Optical methods, although trying, proved the most useful.

Experiment 3. The earlier experiments had shown the relative abundance of carbonates of calcium and magnesium in the solution. It was questioned whether these carbonates were present in the rock itself or whether they had been derived from the action of CO_2 in the solvent water. In order to test this, the experiment was repeated with a fresh lot of 400 g of crushed basalt in 4 l. of CO_2 -free water. Throughout the 6 months of frequent agitation of the solution and subsequent crystallization any possibility of contact with extraneous CO_2 was precluded. Any carbonate that occurred in the various fractions of the solute must therefore have been derived from the basalt itself. The solute was fractionally crystallized as before, giving:

1. Minute (0.02 mm) single dumb-bell-shaped crystals and crystals of

two dumb-bells at right angles to each other of calcite in a colourless isotropic matrix (n approx. 1.49).

2, 3, and 4. Minute dumb-bell-shaped crystals of calcite and few pieces of montmorillonite–nontronite in the colourless isotropic matrix, plus zeolite in fraction 4 only.

5 and 6. Isotropic matrix with green to brown coloured patches, some of which are rosette-like and are polycrystalline; plus tiny spherules of carbonate in 6 only.

7 and 8. Mass of colourless doubly refracting material that shows cross of aggregate polarization. Because of extremely fine grain size refractive index determination was impossible. It may possibly be nesquehonite.

Experiment 4. In order to determine the effect of solutions already charged with soluble components from basalt on fresh basalt, 400 g of basalt in 4 l. of water were agitated from time to time over a period of several months. The solution was decanted and then agitated again with a fresh sample of 400 g of basalt over a period of months. The solution was decanted and evaporated in three stages yielding the following results:

1 and 2. Minute (0.001 mm) dumb-bell-shaped calcite crystals in the colourless isotropic matrix.

3. As for (1) and (2) but the matrix is beginning to crystallize into a polycrystalline aggregate with grey interference colours.

This experiment showed results no different from those in the earlier experiments.

Conclusions

The results bear out the observations and conclusions made in the field and laboratory by Nashar and Davies (1960) that the solutions depositing secondary minerals in the Tertiary basalts from Barrington, New South Wales, are extraneous and cold. In the light of the results, similar experiments are being carried out on individual minerals.

The fact that the assemblage calcite–montmorillonite–heulandite (?) can form under normal atmospheric conditions of temperature and pressure in the vesicles of basalts indicates that it might be wise to merely regard it as a mineral facies and not include it specifically in the zeolite facies of metamorphism (Coombs, 1961).

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References

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