

Eclogites and Water Pressure

N. FRY and W. S. FYFE

Manchester University, England

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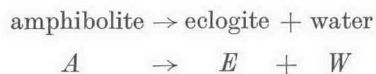
Abstract. Available data on the stability of amphibolites and the basalt-eclogite transition allow an estimate of the stability field of eclogites in wet systems. It appears that if water and load pressures are comparable, eclogites cannot be stable in the crust; the formation of eclogites in the crust requires moderate total pressures and low water pressures. If the reactions forming eclogites occur in essentially dry rocks, their formation may reflect kinetic as well as equilibrium factors.

Introduction

In recent years there has been intense interest in the physical conditions necessary to produce eclogites in the crust of the earth. There is no longer any doubt that omphacite-garnet rocks of approximately basaltic composition can be the product of metamorphism of rocks originally formed at or near the earth's surface.

We shall not attempt here to refer to the various views on the conditions of formation of eclogites but suffice to mention two extremes. YODER and TILLEY (1962) studied the melting behaviour and stability of amphibolites in the basalt system under conditions where excess water was present and P_{H_2O} must be nearly equal to total pressure. As they produced no eclogites and only a wide field of amphibolites up to 10 kb, they concluded that if excess water is present in the basalt system, eclogites are excluded by amphibolites. These experiments at that time could hardly be totally satisfying because pressures were thought to be, in general, too low to form eclogites, even if water had been absent.

ESSENE and FYFE (1967) challenged their conclusions on the basis of observations in the eclogite-amphibolite-glaucophane schist terrances of California. There were two reasons for their doubt of the YODER and TILLEY conclusions. First, minerals with affinities to eclogites (omphacites-garnets) are frequently found as vein and vug-filling minerals suggesting an ample fluid phase. Second, if we consider the reaction:



it is clear that at all moderate pressures:

$$V_A > V_E + V_W$$

and hence the transition $A \rightarrow E$ may occur with increased water pressure.

ESSENE and FYFE went further to suggest that as ΔV of the reaction is quite large and negative and that as the amount of water involved is small, ΔS might

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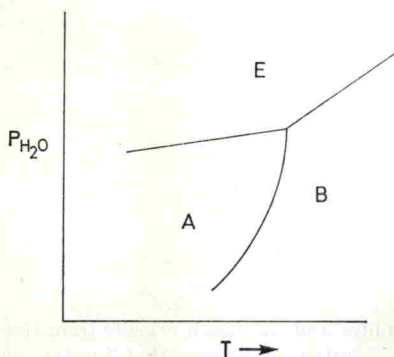


Fig. 1. Form of phase relations between amphibolites (*A*), basalts (*B*) and eclogites (*E*) proposed by ESSENE and FYFE (1967). Melting phenomena have been ignored

also be negative. Hence the phase boundary of the above reaction could have positive slope, even if only at low temperatures, and eclogites could be stable with excess water at low temperatures and moderate pressures. This would lead to a phase diagram as in Fig. 1. Such an $A \rightarrow E$ boundary would be in accord with MIYASHIRO'S (1961) well known facies diagram.

The Amphibolite-Eclogite Transition

At the present time, no direct experimental study of the $A \rightarrow E$ boundary is available. However, data is available which indicates that ESSENE and FYFE'S conclusion is most improbable.

Firstly, the entropies of amphiboles seem rather low on the additivity model (see FYFE, TURNER and VERHOOGEN, 1958) compared to pyroxenes. Thus, if we use the normal approach we might estimate the entropy of tremolite by adding diopside, enstatite, quartz and ice:

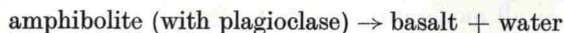
$$S(\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2) = 2 S(\text{CaMgSi}_2\text{O}_6) + 3 S(\text{MgSiO}_3) + S(\text{SiO}_2) + S(\text{ice}).$$

This would give:

$$S_{\text{trem}} = 136.54 = 68.4 + 48.66 + 98.8 + 9.6 \text{ e.u.}$$

The observed entropy of tremolite is 131 e.u., considerably lower than the additivity estimate. If this is also true for hornblendes, then ESSENE and FYFE'S guessed negative ΔS of $A \rightarrow E + W$, looks unlikely. The boundary between amphibolite and eclogite will therefore be negative in slope and continue to go to increasingly high $P_{\text{H}_2\text{O}}$ with lowering of temperature.

More significantly, we now know approximately the positions of the boundaries



and:

