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OPHICARBONATE ROCKS: METAMORPHIC REACTIONS AND POSSIBLE ORIGIN

BY

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In a first approximation, ophicarbonates may be regarded as forming part of a multisystem with the components $\text{CaO-MgO-SiO}_2\text{-CO}_2\text{-H}_2\text{O}$. The prograde reactions in this system can be described for the minerals antigorite, diopside, forsterite, talc, calcite, dolomite and magnesite by 30 equilibria only four of which are independent (Trommsdorff and Evans, 1977a). Adding chrysotile to the system requires another equilibrium. Calculation of these equilibria using experimentally calibrated data yields within the limits of experimental error several possible topologies in $\text{P-T-X}_{\text{CO}_2}$ space for the ophicarbonate phase diagram (Trommsdorff and Evans, 1977b). Only one of these topologies is confirmed by field data (Fig. 1). Ophicarbonate rocks have a limited stability in T-X_{CO_2} space, their equilibrium fluid being always very rich in H_2O .

At surface conditions the pH of fluids emanating from serpentinite and ophicarbonate rocks is considerably higher than in most other rocks (pH 9-12, Pfeifer, 1977). For metamorphic conditions, a similar behavior, i.e. pH 6-7 at 300° C, 0.5-1 kb, in contrast to pH 3-5 in felsic rocks, has been estimated, using the model of fluid-rock interaction proposed by Helgeson (1970) and Helgeson *et al.* (1970), see Table 1. The formation of carbonate minerals in ophicarbonate rocks is conceived to be a precipitation reaction, which can be driven by two processes: (1) Mixing of an alkaline fluid from serpentinites with more acid fluids from felsic or mafic rocks which leads to supersaturation with carbonate minerals, or (2), sudden drop of pressure in a hydrothermal vein system, followed by a separation of the vapour phase (flashing, cf. Arnorsson 1977).

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TABLE 1. — *Example of a fluid composition in equilibrium with an Antigorite-Tremolite-Diopside rock at 300° C, 500bar. It has been calculated by simulating an irreversible dissolution of a peridotite, which ends when equilibrium with a serpentinite paragenesis is reached (Pfeifer 1977, 1979).*

A. Total concentrations			B. Distributed among species		
	mole/kg H ₂ O	ppm		mole/kg H ₂ O	Activity
Na	0.5	11 169	Al ³⁺	—	—
Ca	1.56×10^{-3}	61	Al(OH) ²⁺	—	—
Mg	8.33×10^{-6}	0.19	Al(OH) ₄ [−]	—	—
SiO ₂	4.67×10^{-4}	27	Al(SO ₄) ⁺	—	—
HS	7.70×10^{-8}	0.003	K ⁺	—	—
SO ₄	9.90×10^{-6}	0.92	KCl [°]	—	—
CO ₃	0.0	0.0	KSO ₄ [−]	—	—
Cl	0.5	17 322	Na ⁺	0.47	0.21
OH	1.1×10^{-4}	1.80	NaCl [°]	0.03	0.04
I.st.	0.474	—	Ca ²⁺	1.54×10^{-3}	1.18×10^{-4}
pH	6.61	—	Ca(OH) ⁺	9.35×10^{-6}	4.16×10^{-6}
			Mg ²⁺	2.87×10^{-6}	3.37×10^{-7}
			Mg(OH) ⁺	5.46×10^{-6}	2.43×10^{-5}
			SiO ₂ aq.	4.68×10^{-4}	4.68×10^{-4}
			HS [−]	1.47×10^{-8}	6.18×10^{-9}
			SO ₄ ²⁺	9.60×10^{-6}	3.76×10^{-7}
			HSO ₄ [−]	2.94×10^{-7}	1.31×10^{-7}
			S ₂ [−]	3.41×10^{-9}	1.93×10^{-10}
			H ₂ S [°]	5.99×10^{-8}	7.25×10^{-8}
			CO ₃ ^{2−}	—	—
			HCO ₃ [−]	—	—
			H ₂ CO ₃	—	—
			Cl [−]	0.47	0.19
			HCl [°]	3.36×10^{-7}	4.07×10^{-7}
			OH [−]	9.40×10^{-5}	3.95×10^{-5}
			H ₂ O	5.55×10^1	1.00
			H ⁺	3.33×10^{-7}	2.44×10^{-7}

This proposed origin for ophicarbonate rocks excludes of course not other geologically possible origins i.e. sedimentary or tectonic mixing of serpentine plus carbonate minerals.

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FIG. 1. — Progressive metamorphism of antigorite-ophicarbonate rocks, Val Ventina, Malenco, Italy in comparison to the calculated stable T - X_{CO_2} topology for the ophicarbonate system ($\text{CaO-MgO-SiO}_2\text{-CO}_2\text{-H}_2\text{O}$) at three kilobars total fluid pressure.

Vertical streaks indicate occurrence of assemblages (see also Trommsdorff and Evans, 1977b). Abbreviations: *A* = antigorite, *Cc* = calcite, *Di* = diopside, *Do* = dolomite, *Fo* = forsterite, *M* = magnesite, *Tc* = talc, *Tr* = tremolite.

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