TYPE A - TYPE C ECLOGITE TRANSITION IN A XENOLITH FROM THE MOSES ROCK DIATREME - FURTHER EVIDENCE FOR THE PRESENCE OF METAMORPHOSED OPHIOLITES BENEATH THE COLORADO PLATEAU

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A garnet clinopyroxenite xenolith from Moses Rock records the metamorphic transformation of the primary assemblage garnet (Py_{73} Alm_{17} $Gross_{17}$ $Andr_{2}$ $Spess_{1}$) and clinopyroxene (Aug_{83} Jd_{11} Ac_{5}) into the secondary assemblage magnesian chlorite, garnet (Py_{40} Alm_{30} $Gross_{24}$ $Andr_{3}$ $Spess_{2}$), and omphacite (Aug_{55} Jd_{40} Ac_{5}). Large pyropic garnets are surrounded by haloes of magnesian chlorite which is intergrown with less pyropic, fine-grained euhedral garnet and omphacite. Omphacite also overgrows some of the anhedral clinopyroxenes of the original assemblage. Textures and mineral compositions indicate that the primary assemblage corresponds to that of a high P-high T Type A eclogite which was hydrated under high P but lower T to a chlorite-bearing eclogite of Type C affinities (Coleman et al., 1965). The presence of this unusual xenolith and a comparison of its subsolidus history with that of other ultramafic inclusions from the Four Corners kimberlites (Table 1) have several important implications for the Colorado Plateau.

<u>Nature of uppermost mantle beneath the Colorado Plateau:</u>

Although a Type A to Type C eclogite transition has not been documented previously in a single hand specimen, a similar reaction was inferred by Banno and Yoshino (1965) in the Bessi district of Japan where mantle-derived garnet-diopside eclogites (Type A) were transformed by high P-low T Sanbagawa metamorphism into hydrated garnet-omphacite rocks. Similar assemblages were produced by high P-low T metamorphism also in Alpine ophiolites (Moeckel, 1969). In the Sanbagawa Belt as well as in the Alps, retrograde Type A eclogites occur together with Type C eclogites formed by progressive metamorphism of basic igneous rocks. The Alpine meta-ophiolites contain titanoclinohumite found also at Moses Rock (McGetchin et al., 1970), Buell Park (Aoki et al., 1976), and Green Knobs (Smith, 1977a) and inferred by Smith (1977a) to be part of the hydrous alteration assemblage of peridotites. The fact that all hydration reactions recorded in the ultrabasic xenoliths from the Four Corners kimberlites are known also from metamorphosed ophiolites exposed at the earth's surface (Table 1) and the association of these retrogressed xenoliths with progressively metamorphosed Type C eclogites strongly suggest a derivation of this xenolith suite from metamorphosed ophiolitic rocks beneath the Colorado Plateau. This supports earlier proposals (Helmstaedt and Doig, 1975; Råheim and Green, 1975; Mercier, 1976) that these xenoliths represent fragments of oceanic lithosphere subducted and underplated beneath the Precambrian basement of the Plateau.

<u>Feasibility of establishing paleogeotherms and upper mantle models for Plateau:</u>

Using xenolith and xenocryst pyroxene compositions for calculations of pressures and temperatures of equilibration and assuming that differences in pressures represent differences in depth of derivation, paleogeotherms have been constructed for the Colorado Plateau (McGetchin and Silver, 1972; Mercier, 1976). As it is now well established that all types of ultrabasic xenoliths were modified by hydration reactions prior to the kimberlite eruptions, it becomes apparent that P-T assignments based on mineral compositions of metastably surviving protolith assemblages cannot be used to establish paleogeo-

TABLE 1. BRIEF COMPARISON OF SUBSOLIDUS HISTORY OF ULTRAMAFIC XENOLITHS FROM FOUR CORNERS KIMBERLITES

Xenolith-type	Chlorite-garnet pyroxenite (this paper)	Chlorite-garnet peridotite (unpublished data)	Hydrated spinel websterite (unpublished data)	Serpentine schists (McGetchin & Silver, 1972). Various hydrated peridotites (Smith, 1977a). Foliated chlorite-serpentine schists (unpublished data)	Type C eclogites. Jadeite-clinopyroxenites (Helmstaedt & Doig, 1975; McGetchin & Silver, 1972)
Earliest recognizable protolith	Pyrope-diopside rock (Type A eclogite)	Garnet peridotite (Gavasci and Helmstaedt, 1969)	Spinel-pyroxenite	Spinel peridotite, possibly garnet peridotite (Smith, 1977b)	Basic to intermediate igneous rocks (Helmstaedt et al., 1972)
Pre-eruption subsolidus history	No signs of deformation in primary minerals	Some plastic strain	Pyroxene exsolution, deformation, recrystallization to spinel websterite	Pyroxene exsolution, deformation, recrystallization to spinel peridotite (Helmstaedt et al., 1972)	Metasomatic alteration, possibly spilitization. Synkinematic metamorphism to lawsonite-bearing Type C eclogite, K_D^* (mineral Cores) ~30 (Råheim & Green, 1975)
	Formation of magnesian chlorite + less pyropic garnet + omphacite, $K_D^* = 8.3$	Alteration of garnet to magnesian chlorite (unpublished data)	Apparently static alteration to pargasite + chrome spinel + corundum + chlorite + clinozoisite	Sequence of increasing hydration including formation of amphibole, chlorite, titanoclinohumite, and antigorite (Smith, 1977a). Static and synkinematic	Formation of atoll garnets, jadeite-rich rims on pyroxenes, more pyropic rims on garnets, $K_D^* = 8.5-10$ (Råheim & Green, 1975; unpublished data). Alteration of lawsonite to zoisite
Post-eruption alteration				static serpentinization	
Surface occurrence of similar rocks	Meta-ophiolites, Alps, Japan (Banno & Yoshino, 1965; Moeckel, 1969)	Meta-ophiolites, Alps (Moeckel, 1969)	Meta-ophiolites, France (Lashnier, 1976)	Common in meta-ophiolites. See Smith (1977b)	Type C eclogites (Coleman et al., 1965)

$$* \; K_D = \frac{(FeO/MgO)\,Ga}{(FeO/MgO)\,Cpx}$$

therms and upper mantle cross-sections for the Plateau. At best, it is possible to infer P-T conditions of metamorphism prior to eruption, but even these may not represent the conditions at the time of eruption. Iron-magnesium distribution coefficients of the garnet-omphacite pair from the metamorphosed Type A eclogite xenolith correspond to those determined for the rims of garnets and pyroxenes from the progressively metamorphosed Type C eclogites (Table 1) suggesting that, like in the mentioned surface occurrences, the two rock types may have existed at a similar structural level beneath the Plateau. The conditions for hydration of the other ultrabasic xenoliths (except for late serpentinization) are compatible with those required for the Type A-Type C transition. Although a certain depth range may have been sampled, compelling evidence to infer that the xenoliths were incorporated by the kimberlite at a depth much greater than indicated by the metamorphic assemblages does therefore not exist.

Mechanism and timing of uplift of the Colorado Plateau:

While their emplacement poses a formidable geotectonic problem, the presence of the partially hydrated ultrabasic rocks and eclogites under the Plateau at the time of the kimberlite eruptions may help to solve another problem, that of mechanism and timing of uplift of the Colorado Plateau. Hess (1955) mentioned the volume increase due to serpentinization as a possible reason for uplift. We propose that the volume increase caused by the hydration reactions preceding serpentinization is responsible for a significant part of this uplift. There is also the possibility of a link between the hydration of the underplated meta-ophiolites and the Laramide basement uplifts east of the Colorado Plateau.

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