values of K_0' range from 1.05 to 3.0 (excluding enstatite, see later section), whereas the revised values range from 2.74 to 3.45.

Some independent arguments can be made to further justify the above results. In fact, it may be noted that since the shock-wave data, in effect, determine relations between Φ_0 and ρ_0 and K_0' and ρ_0 (or Φ_0), then either the seismic equation of state (a relation between Φ_0 and ρ_0) or any other acceptable criterion, such as arguments on the magnitude of Φ_0 or K_0', could be used as an additional constraint. That an additional constraint is required was pointed out by *D. L. Anderson and Kanamori* [1968]. Arguments are given below on the magnitudes of both K_0' and Φ_0.

Very low, negative, or rapidly fluctuating values of dK/dP in minerals are usually only observed in association with the collapse of porous material, during phase changes, or at low pressures in some glasses [e.g., *Manghnani et al.*, 1968; *Fritz and Thurston*, 1970]. Since glasses do not have a highly ordered crystal structure, and the other two cases involve the

disruption of an ordered structure, these examples do not give any reason to expect anomalous behavior of dK/dP over a large pressure range in materials with well defined structures. Further, laboratory measurements of K_0' for the low-pressure phases of dense minerals usually yield values in the range 4.0 to 5.4 [e.g., *O. L. Anderson et al.*, 1968]. The present results, based on the revised seismic equation of state, seem to accord with the conjecture that dK/dP of the high-pressure phases at zero pressure are less than dK/dP of the low-pressure phases, and should tend smoothly, and perhaps monotonically, toward the Thomas-Fermi limit at high pressures. They are also consistent with the observation [*O. L. Anderson et al.*, 1968] that high-density minerals of a given mean atomic weight have lower values for dK/dP than low-density minerals. There is one more shred of evidence bearing on the dK/dP of high-pressure phases of silicates. *D. L. Anderson and Jordan* [1970] estimated the zero-pressure properties of the lower mantle from seismic data, and obtained a dK/dP of 3.3. This
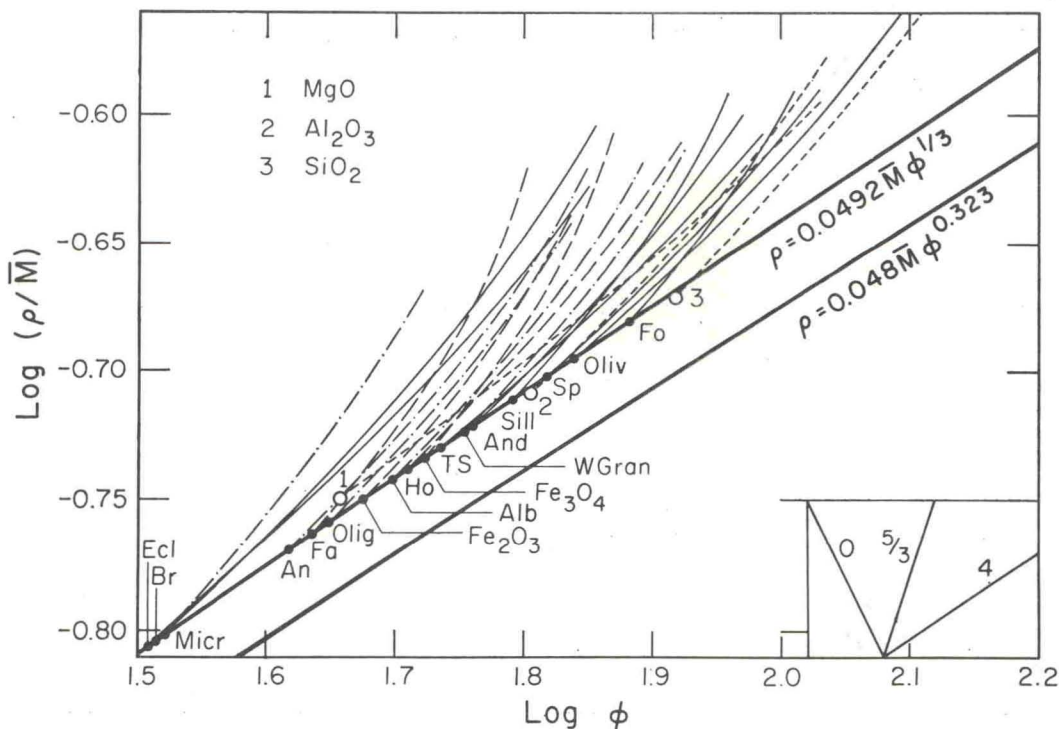

Fig. 2. As in Figure 1 for adiabats derived using equation 6. Solid straight line is revised seismic equation of state line, equation 6. Solid straight line of equation 5 is also shown.

value is appropriate for a temperature of the order of 1600°C, and would be lower at room temperature. Of the minerals studied in this paper olivinite and Twin Sister's dunite are the most pertinent for the lower mantle, and they have dK/dP of 3.35 and 3.45, respectively.

Before discussing other consequences of the use of the revised seismic equation of state, it should be pointed out that the rapid decrease of dK/dP with pressure, which is seen especially in some of the results of *Ahrens et al.* [1969], is due in part to an undesirable char-

acteristic of the Birch-Murnaghan equation. In a few cases, this was further aggravated by another artifice of the calculation. These points will be discussed in the next section.

Further effects of the revision of the seismic equation of state are to reduce the zero-pressure densities, usually by about 3 to 5%, and to reduce Φ_0 by 20% or more. In Table 2 the old and new densities and Φ's are compared to the ρ and Φ obtained by taking the molar average of V and Φ of the component oxides of each substance. The densities are close to or slightly

TABLE 2. Comparison of Original and Revised ρ_0 and Φ_0 with Those of the Isochemical Mixture of Oxides, and Proposed Crystal Structures and Densities of High-Pressure Phases

	ρ_0				Φ_0					Density of Structure
	Equations		$\psi_0 =$		Equations		$\psi_0 =$		Proposed Structure	
	5	6	0.051	Oxides	5	6	0.051	Oxides		
Forsterite	4.31	4.18		3.85	103	76		62	K_2NiF_4	4.12
Olivinite I	4.58	4.28		4.0	106	69		60	K_2NiF_4	4.25
Twin Sisters dunite	4.12	3.94		4.04	82	55		60	Sr_2PbO_4	4.04
									olivine (LS)	3.39
Hortonolite dunite	4.75	4.59		4.64	70	52		55	Sr_2PbO_4	4.64
									olivine (LS)	4.35
Fayalite	5.31	5.03	4.82	5.29	63	43	34	50	Sr_2PbO_4	5.29
									olivine (LS)	5.41
									spinel	4.8
Hematite	5.96	5.70	5.44	...	67	48	37	...	perovskite	5.8
									β-rare earth	5.56
									corundum (LS)	6.05
Magnetite	6.30	6.11	6.00	5.54	71	53	45	43[c]	$CaFe_2O_4$	5.84
									spinel: $Fe^{2+}Fe_2^{3+}(LS)O_4(N)$	5.6
									$Fe^{2+}(LS)Fe_2^{3+}O_4(I)$	5.45
									$Fe^{3+}(HS)Fe^{2+}(LS)Fe^{3+}$	
									$(LS)O_4(I)$	5.8
									$CaFe_2O_4$: $Fe^{2+}Fe_2^{2+}(LS)O_4$	6.4
									$FeO(LS) + Fe_2O_3$	
									$(\beta$-rare earth)	6.1
Spinel	4.19	4.03		3.86	91	66		59	$CaFe_2O_4$	4.13
Sillimanite	4.00	3.94		4.09	80	62		70	pseudobrookite	3.81
Andalusite	3.95	3.84		4.09	77	57		70	pseudobrookite	3.81
Enstatite	4.20	3.93[a]		3.98	96	...		66	ilmenite	3.76
									perovskite	4.25
Bronzitite	3.74	3.33		4.08	57	33		64	garnet	3.64
									ilmenite	3.85
Anorthosite	3.71	3.57		3.91	56	41		...	$J + G + K + S$[b]	3.54
									hollandite	3.85
Oligoclase	3.69	3.57		3.86	40	45		...	$J + G + K + S$	3.52
									hollandite	3.86
Albitite	3.80	3.69		3.85	67	50		...	$J + G + K + S$	3.51
									hollandite	3.85
Microcline	3.51	3.36		3.86	45	33		...	$(J + S)$	(3.20)
									hollandite	3.84
Westerly granite	3.96	3.90		4.07	73	57		...	hollandite + stishovite	3.94
Diabase, Centreville	3.79	(3.63)		4.01	...	...		...	hollandite + garnet	3.75
Diabase, Frederick	3.77	(3.61)		4.08	...	...		...	hollandite + garnet	3.75

[a] Hugoniot.

[b] J = jadeite, G = grossular, K = kyanite, S = stishovite.

[c] Uses $\Phi_0(Fe_2O_3) = 48$.