

SOME TRACE ELEMENTS IN RUTILE FROM ECLOGITES AND THEIR IMPLICATIONS

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A study of paragenesis and compositions of rutiles in eclogites has been made in order to assess the model of partial melting of eclogite to produce andesitic rocks in subduction zones.

Rutile appears as an accessory phase in almost all eclogites because there is no other phase capable of accommodating titanium. The high pressure of omphacite formation favours the entry of aluminium into 6-fold rather than 4-fold co-ordination (THOMPSON, 1947) and formation of the titanium-bearing pyroxene component $\text{CaTiAl}_2\text{O}_6$ is precluded under these conditions. Iron may enter the omphacitic pyroxene as $\text{CaFeSi}_2\text{O}_6$ and/or $\text{NaFe}^{3+}\text{Si}_2\text{O}_6$ depending on the oxidation state. Pyrope-almandine garnets are also low in titanium. This means that unless amphibole or mica is present as a primary Ti-bearing mineral, rutile occurs as a separate phase.

Rutiles from three eclogites have been studied. Two (New Guinea 295, Tasmania EC30) are from amphibolite terrains and a third (California EC84) is from a blue schist terrain. Rutile from the New Guinea eclogite (295) was analyzed for Cu, Ni, Sc and V by optical emission spectroscopy. V was found to be high (365 ppm) but the other elements were not detected.

The specimens were analyzed for Zr, Hf, Sn, W, Mo, Y and the rare earth elements using a spark source mass spectrometer (method of TAYLOR, 1971). The results are shown in Table 1.

Table 1 Some trace elements in rutiles from eclogites

	295 New Guinea	EC20 Tasmania	EC84 California
Zr	689	910	168
Hf	17.5	17.7	7.8
Zr/Hf	39	51	22
Nb	261	>300	228
Zr/Nb	2.64	<3.0	0.74
Sn	38.6	17.9	5.5
W	12.5	8.2	1.6
Mo	33	10.2	nd*
Y	0.44	1.24	15.2
U	4.2	.48	nd*
Th	0.05	.34	nd*
Th/U	.01	.71	nd*

* nd = not detected.

All values in ppm

There is a large but systematic variation of these elements between samples. For instance, Sn, W and Mo all decrease as Zr decreases. This systematic variation is probably a reflection of their variation in abundance in the type of basalt metamorphosed. The New Guinea eclogite was probably derived from an alkali basalt whereas the Californian eclogite was probably from an ocean-floor basalt.

As expected from previous studies on terrestrial and extraterrestrial rutiles, the eclogite rutiles are high in Zr and Nb. Hafnium is also high and the Zr/Hf ratios are much the same as those of basalts. On the other hand Nb is high relative to Zr, the Zr/Nb ratios of rutiles being about an order of magnitude less than those of basalts.

The quadrivalent elements, Sn, W and Mo are also enriched in rutiles possibly by as much as an order of magnitude over basalt abundance.

Rare earth elements are low and could not be quantitatively determined because of interference effects, but there is clearly an enrichment in light relative to heavy rare earth elements. In two samples the low Y values tend to confirm this suggested rare earth pattern.

Uranium is unexpectedly high and thorium very low in the New Guinea sample. This is not so in the other two samples although both elements are sufficiently high in rutile from the Tasmanian eclogite to indicate a Th/U ratio of less than one. Basalts have a ratio greater than one.

It has been suggested that andesites and related rocks of island arcs are produced by partial melting of basaltic rocks in subduction zones (GREEN and RINGWOOD, 1968). The residue of this process is eclogite. It is assumed in the following discussion that the subducted and partially melted basalt is oceanfloor tholeiite. GREEN and RINGWOOD (1968) have shown that major element compositions of near liquidus pyroxenes and garnets produced from basaltic material under high pressure are consistent with the residual eclogite hypothesis.

Subduction zone rocks of all types including island arc tholeiites, high-Al basalts and andesites are all characterized by very low Ti contents. These low titanium values can be explained if rutile is a minor phase in the eclogite residuum (GILL, 1972). The low abundances in these rocks of several other elements that can be concentrated in rutile are also explained if refractory rutile occurs in residual eclogite. For example, Zr is less abundant in arc tholeiites than in ocean floor basalts, and andesites have similar average Zr contents to ocean floor basalts (Table 2).

In contrast Nb is lower by at least a factor of two in subduction zone rocks: this is explained by the very low Zr/Nb ratios found in all the rutiles of eclogites.

Zr/Hf ratios are not discernibly different in ocean floor basalts and andesites. This is compatible with the fact that the Zr/Hf ratios in rutiles are similar to those in basalts and andesites.

Insufficient data are available on Sn, W and Mo, in basalts and andesites. Because of their high values in rutiles we predict that they will be low in andesites. The increase in Th/U ratios of subduction zone volcanics relative to those of ocean floor basalts (Table 2), could be enhanced by the presence of rutile in the residuum since rutile takes up U preferentially to Th.

Table 2 Average values of selected trace elements in ocean floor tholeiites and subduction zone volcanic rocks

	Ocean floor Tholeiites	Island Arc Tholeiites	Andesites
SiO ₂ (%: Typical values)	48-50	48-53	55-60
TiO ₂	1.50	0.80	0.45
Zr (ppm)	95	46	96
Nb "	7	~0.5	4
Zr/Nb	13	-	24
Hf (ppm)	2.4	-	2.5
Zr/Hf	40	-	38
Sn (ppm)	1-2	-	0.4
U	0.1	0.27	0.52
Th	0.15	0.49	1.31
Th/U	1.5	1.8	2.5

Data from BROOKS (1970), CANN (1971), CHAPPELL and WHITE (unpublished) GILL (1972), HAMAGUCHI and KURODA (1969), TAYLOR and WHITE (1966).

It is concluded that Ti, Zr, Nb and possibly Sn, W, Mo abundances in subduction zone rocks such as andesites can be qualitatively explained using the model of andesite magma genesis by partial melting of ocean floor tholeiite.

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