Titanite reaction textures around ilmenite in amphibolite-facies rocks: Fluid induced?

(1 fig.)

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Titanite (general formula $XYOZO_4$, ideally $CaTiOSiO_4$) is an accessory mineral that may contain elevated abundances of both REE (substituting for Ca) as well as high-field-strength-elements. It can crystallise both as a primary and as a lower-T secondary phase in igneous environments. It also commonly forms during mid- to high-grade metamorphic processes. As a consequence, titanite can serve as a valuable tool for the modelling of geochemical processes.

In the amphibolite-facies portion of two regional, amphibolite to granulite-facies metamorphic traverses (Val Strona area, Ivrea-Verbano Zone, N. Italy; cf. Harlov and Förster (2002) J Petrol 43, 769, and Tamil Nadu, S. India; Harlov and Hansen, Lithos, submitted), titanite is observed either as separate grains or else riming ilmenite (Fig. 1a). Individual titanite grains are often associated with ilmenite or contain ilmenite inclusions (Fig 1b). Titanite is absent in the granulite-facies rocks of either traverse. (Y+REE)-content in the titanite is variable which translates into light and dark regions under BSE imaging (Fig. 1b). The following Table reports average microprobe analyses of both individual titanite as well as rims around ilmenite grains for four samples representing amphibolite-facies rocks from the Tamil Nadu traverse:

Table 1 Here, 95J3I1 represents the northernmost sample and 93F2L1 the southernmost sample, closest to the granulite-facies portion of the traverse.

	95J3I1	95J3H5	93F2K2	93F2L1
SiO_2	29.88	30.01	30.11	29.86
TiO_2	36.90	36.46	34.93	37.13
Al_2O_3	1.21	1.46	2.71	1.37
Fe_2O_3	1.33	1.44	1.89	1.27
MnO	0.09	0.10	0.11	0.08
CaO	27.61	27.47	28.12	28.12
Y_2O_3	0.12	0.17	0.04	0.06
La_2O_3	0.12	0.10	0.07	0.05
Ce_2O_3	0.47	0.43	0.31	0.23
Pr_2O_3	0.09	0.10	0.08	0.06
Nd_2O_3	0.31	0.30	0.15	0.14
Sm_2O_3	0.05	0.06	0.03	0.04
Gd_2O_3	0.05	0.06	0.03	0.04
Dy_2O_3	0.04	0.04	0.02	0.03
Ho_2O_3	0.02	0.03	0.03	0.03
Er_2O_3	0.01	0.03	0.02	0.02
Yb_2O_3	0.01	0.01	0.01	0.02
Lu_2O_3	0.02	0.02	0.02	0.01
F	0.08	0.17	0.94	0.15
total	98.42	98.45	99.62	98.89
Σ(Y+REE)	1.32	1.35	0.81	0.74

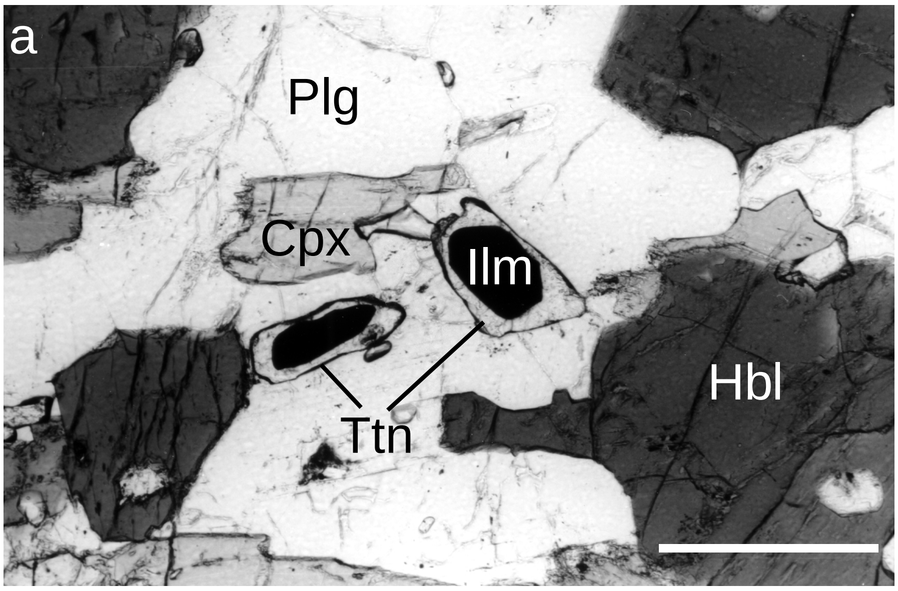

Fig. 1a Transmitted light photograph showing an example of titanite rimming ilmenite grains in a clinopyroxene-bearing amphibolite-facies rock located in the Val Strona traverse, Ivrea-Verbano Zone, N. Italy.

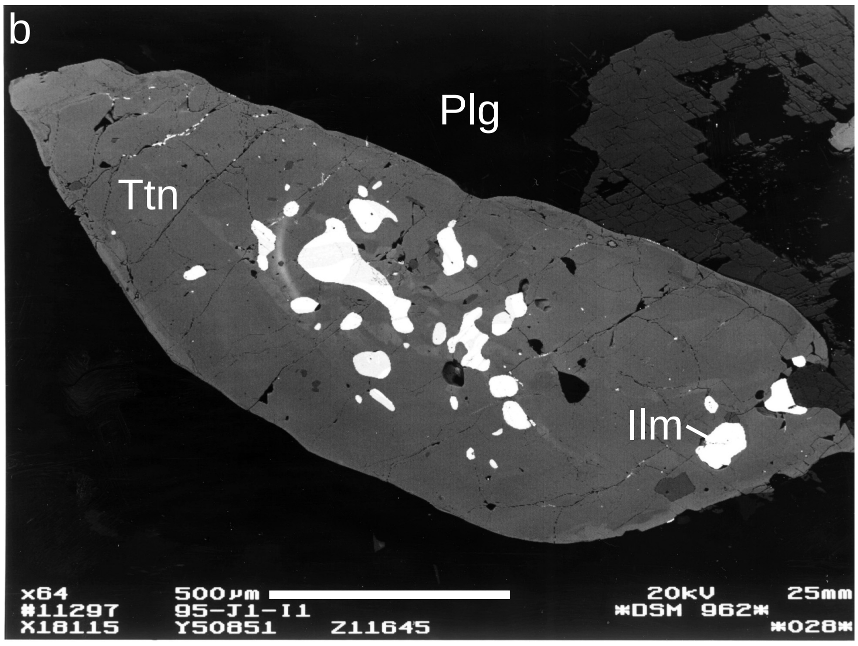

Fig. 1b Back-scattered electron photograph that shows an example of a semi-euhedral titanite with rounded remnants of a hemo-ilmenite grain in the interior. Note the subtle light and dark shading in the titanite. Lighter areas are slightly more enriched in (Y+REE) than darker areas.

Titanite reaction rims around ilmenite suggest that the ilmenite has interacted with a Ca and (Y+REE)-bearing fluid in the amphibolite-facies terranes. The most likely composition of this fluid would be a $CaCl_2$ brine, with a water activity high enough and/or at a pressure-temperature low enough to prevent amphibole breakdown to orthopyroxene + clinopyroxene. Instead, the ilmenite was attacked and rims of titanite formed, with the Fe most likely removed as $FeCl_2$. The increased (Y+REE) content of the titanite suggests that this fluid also contained a (Y+REE)-component, especially enriched in the LREE. The relatively low pressures seen in these amphibolite-facies terranes (400–500 MPa) do not lend any credence to the idea that these rims could represent some sort of decompression reaction between the ilmenite and a Ca-bearing phase such as plagioclase as has been reported for high pressure (>1 GPa) mafic rocks. Nor is there any evidence to suggest that the Ca came directly from neighbouring plagioclase and even if it did – it would have had to has been aided by fluids, again most probably in the form of brines.

These hypotheses need to be tested by experimental work under amphibolite-facies pressures and temperatures. Such experiments would involve natural endmember ilmenite and Si and (Y+REE)-bearing $CaCl_2$ brines, both with and without plagioclase. Discovery of other occurrences of titanite rimming ilmenite in moderate to low pressure metamorphic environments, where brines are known to have facilitated metasomatic alteration, would shed additional light into the question where and why these assemblages form in nature.