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RUTILE-ILMENITE INTERGROWTHS

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The association of rutile and ilmenite as separate individuals is not unusual as a product of igneous rocks, of some pegmatites and certain high temperature veins, and of some contact metamorphic deposits. Mechanical mixtures of the two minerals, representing approximately simultaneous crystallization, have been less frequently recorded. This statement is limited to primary occurrences, and does not include alterations of the one mineral into the other.

One of the common alterations of rutile is to ilmenite, all stages in the process being observed in thin sections under the microscope. It becomes necessary, then, to distinguish between primary and secondary ilmenite, when it is found in intimate relations with rutile. Such differentiation is usually easy, except in those cases where alteration has advanced to the final stage in the process. No attempt, however, is made in this paper to formulate the criteria for distinguishing between primary and secondary ilmenite in association with rutile, since they are to be published in detail elsewhere.

Recent study by the writer of an interesting occurrence of rutile-ilmenite in a large quartz vein illustrates both primary intergrowths of ilmenite and rutile, and secondary ilmenite derived by alteration from rutile. Probably the secondary material is the greater in amount in the thin sections studied.

The vein is located in Franklin County, Virginia, less than one mile south of Roanoke River and one mile west of the entrance of Indian Creek into Roanoke River, and 15 miles southeast of Roanoke City. It has been prospected and considerable rutile is reported to have been obtained. The vein occurs in the crystalline schists of the western margin of the Piedmont Plateau province and about 8 miles east of the main Blue Ridge. Where crossed by the highway the vein has an elevation of 300 meters (1000 feet) above sea level. It appears not to exceed 15 meters (50 feet) in width, and is composed almost throughout of white granular sub-transparent crystalline quartz of remarkable purity. Locally, rutile and ilmenite occur, but they are the only other minerals observed in the vein.

The rutile and ilmenite are intimately associated, in clusters of crystals, both exhibiting their usual characteristic physical properties such as color, hardness, streak, etc. All crystals show the tetragonal-prismatic habit of rutile, without end faces. They measure up to 6½ cm. (2½ inches) long by 1 cm. (2/5 inch) broad. The prism faces are usually striated and furrowed. Twin crystals are rare.

Careful megascopic study of the material collected by the writer showed that some crystals were composed practically entirely of rutile, and some formless massive individuals entirely of ilmenite, but the bulk of the crystals presented a mixture of red-brown rutile and black ilmenite. This conclusion is confirmed by the microscopic study of thin sections, since not a single one of the many thin sections examined showed rutile free from admixture with ilmenite. In general the crystals exhibit: (1) primary intergrowths of the two minerals, and (2) alteration of rutile to ilmenite, in which the important stages in the process can be traced. In both cases the crystal form is that of rutile. Similar intergrowths of rutile and ilmenite, in formless masses, occurring in granite pegmatites in Virginia, have been described.[1] The primary intergrowths of the two titanium minerals have their analogy in the titaniferous magnetites, which are now well known to be magnetite containing mechanically entangled ilmenite.

In order to account for iron oxide present in analyses of rutile, Brögger and others[2] suggest that it be considered as the compound ferrous titanate [$Fe(TiO_3)$] in isomorphous mixture with titanyl titanate [$(TiO)(TiO_3)$]. This is based largely on theoretical

[1] Watson, Thomas L. and Taber, S.: *Bull. III-A, Va. Geol. Survey*, 248–258, especially Pl. XXXVI, Fig. 1, 1913.

[2] Schaller, W. T.: U. S. Geol. Survey, *Bull.* **509**, 9–39, 1912. (Includes references to Brögger, W. C., and Prior, G. T. and Zambonini, F., on isomorphous relationships of the rutile group.)

grounds, since, however likely such relationships, Fe'' and (TiO)'' are assumed, and as Schaller states not yet proved, to be isomorphous. Holden[3] has shown that it is possible to calculate the specific gravity of this supposedly isomorphous constituent. It is interesting to note, however, that the value he obtained, 4.77, is essentially identical with those given in Dana's System for the purer forms of ilmenite.

It seems to the writer unnecessary to assume isomorphism of rutile and a theoretical compound with the same chemical formula as ilmenite, not yet known to occur in nature. In the case here described there can be no question as to the presence of admixed ilmenite. The titaniferous magnetites offer a parallel case, ilmenite and magnetite not being isomorphous.[4]

Many supposed cases of isomorphism among sulfide minerals have been shown by critical study from modern viewpoints to represent mechanical mixtures.[5] The writer is convinced that this relationship also holds in many instances among opaque oxides.

TABLE I. ANALYSES OF RUTILE FROM VIRGINIA AND NORWAY

(William M. Thornton, Jr., Analyst)

	I	II	III	IV	V
TiO_2	97.30	80.85	98.80	95.71	97.68
SiO_2	.12	.06	.26	.92	1.06
Cr_2O_3	.05	.03	.07	.02	.39
V_2O_3	.26	.17	.20	.15	.55
FeO	2.21	18.81	1.68	2.35	.81
MnO	.09	.14	n. d.	Tr.	d. d.
H_2O	.10	.04	n. d.	n. d.	n. d.
	100.13	100.10	101.01	99.15	100.49
Sp. Gr.	4.272		4.21	4.196	4.225

I. Rutile from rutile-bearing quartz vein, Franklin County, Virginia.
II. Rutile-ilmenite from rutile-bearing quartz vein, Franklin County, Virginia.
III. Rutile from rutile nelsonite, Nelson County, Virginia.
IV. Rutile from rutile-bearing syenite, Nelson County, Virginia.
V. Rutile from rutile aplite (kragerite), Kragero, Norway.

[3] Holden, Edw. F.: *Am. Min.*, **6**, 100–103, June, 1921.

[4] Warren, C. H.: *Am. Jour. Sci.*, **25**, 12–38, 1908; ibid., **33**, 263–277, 1912. *Econ. Geol.*, **13**, 419–446, 1918, and Singewald, J. T.: *Bull.* **13**, *U. S. Bureau of Mines*, 1913. *Econ. Geol.*, **8**, 207–214, 1913.

[5] Wherry, Edgar T.: *J. Wash. Acad. Sci.*, **10**, 488, 1920. Foshag, W. F.: *Am. J. Sci.*, **1**, 444-446, 1921.

It is well known that in the past chemists have not always been careful to insure homogeneity of the material analyzed. For this and other obvious reasons, microscopic study of the material to be analyzed should precede chemical analysis. Rutile which sometimes appears entirely fresh in hand specimens may show alteration in thin sections under the microscope. It seems not improbable, therefore, that the iron present in most analyses of rutile has been derived in part from secondary ilmenite.

Chemical analyses of the rutile and rutile-ilmenite from the Franklin County, Virginia, rutile-bearing quartz vein are given in columns I and II of Table I. There are also given in the table for comparison recent accurate analyses (III to V) of rutile from other well-known localities in Virginia and Norway.

The possible effect of the presence of Cr_2O_3 and V_2O_3 in rutile, as shown in all recent accurate analyses, has been discussed elsewhere by the writer.[6] Recasting the analyses in the table below by allotting FeO to TiO_2 to form ilmenite ($FeO.TiO_2$) the mineral composition in terms of rutile and ilmenite is:

TABLE II. MINERAL COMPOSITION BASED ON ANALYSES IN THE ABOVE TABLE
(Numbers correspond in the two tables.)

	I	II	III	IV	V
Rutile	94.80	59.92	96.96	93.04	96.80
Ilmenite	4.71	39.67	3.50	5.02	1.67
Rest	.62	.44	.53	1.09	2.00
	100.13	100.03	100.99	99.15	100.47

The analysis in column II clearly shows a mixture of rutile and ilmenite, in which rutile is in largest amount. Since the entire crystal yielding the results was used in the analysis and none remained for the preparation of a thin section for microscopic study, it is not possible to definitely state whether the ilmenite was primary or secondary or partly both. However, from microscopic study of thin sections cut from similar crystals, it is considered probable that the ilmenite was in part secondary, derived by alteration from rutile.

The writer's conclusion is that the iron shown to be present by analyses of rutile is derived from mechanically admixed ilmenite, and not from chemical mixture of a supposedly isomorphous iron compound.

[6] Watson, Thomas L.: *J. Wash. Acad. Sci.*, 2, 431–434, Nov. 4, 1912.