12. Contribution to the Geochemistry of Tungsten

By

Ivar Oftedal

ABSTRACT.—By spectrochemical analysis of Nb–Ta minerals (columbite, samarskite–yttrotantalite, fergusonite, euxenite–blomstrandine, ilmenorutile) from a number of Norwegian granite pegmatites, tungsten concentrations from about 0.01 % up to several per cent have been recorded. The majority of the results fall within the range 0.1 %–1 % W, the most common value being about 0.3 %. Even the highest concentration observed, about 3 % W, is evidently far below the limit of "saturation". The pegmatite-rich areas in Østfold and Iveland show nearly the same calculated average for their Nb–Ta minerals: 0.5–0.6 % W. In the Arendal district the average value seems to be remarkably low, hardly more than 0.05 %.

The scope of the present investigation is restricted in two ways. Firstly the material examined includes Norwegian pegmatite minerals only. Secondly only tungsten concentrations higher than about 100 p.p.m. are recorded, so that all the figures given below represent very strong tungsten enrichments as compared with average values for common rocks.

The tungsten determinations were made by spectrochemical analysis, applying a "Hilger Large" quartz spectrograph with a rotating stepped sector in front of the slit. The standard mixtures, containing 6–1–0.1–0.01 % W, were made from a columbite which had been found to be very poor in W, and wolframite. Carbon electrodes were used, the samples being mixed with carbon powder and placed in the cathode. The spectrograms were taken by J. HYSINGJORD, F. WOLFF and S. KOLLUNG.

The W lines are relatively insensitive, and many of them are inconvenient because of coincidences etc. In the present case the W line 2831.378 was found to be the most reliable. It nearly coincides with the Ti line 2831.406, and this would seem to be fatal, as some of the minerals to be examined are very rich in Ti. However, it was found that this Ti line is really very weak even in spectrograms of minerals like rutile, ilmenite and sphene, and in addition it can just be seen in the spectrograms that its coincidence with the W line is not quite exact. Therefore W concentrations down to about 0.01 % may be observed even in Ti minerals. The coincidence with the weak Zr line 2831.37 is irrelevant as none of the examined minerals contain notable quantities of Zr. The working curve was based on direct intensity readings of the selected W line, utilizing the intensity steps due to the stepped sector in the standard spectrograms (no internal standard). This, of course, will not give any high degree of accuracy. However, the resulting curve (log p.p.m./no. of vanishing step) turned out to be a nearly straight line and therefore appears to be fairly

reliable. The limits of error of the W determinations made by means of this curve may be $\pm 50\%$ at most. The observed variations in the W contents are much greater than this.

Part of the material examined was kindly supplied from the collections of the Mineralogisk-geologisk museum in Oslo, some of the specimens being specially selected by the present Director of the Museum, Dr. H. NEUMANN. The specimens come from Norwegian granite pegmatites, especially in the Moss district and the Iveland–Evje district north of Kristiansand.

It is well known that W may replace Nb and Ta in minerals to a considerable extent. H. BJØRLYKKE (1935) has demonstrated this amply and even found as much as 13% WO_3 in a columbite from Iveland. This diadochy is also in accordance with the similarity of the ionic radii. Having examined spectrograms of numerous pegmatite minerals, it also appears to me that Nb and Ta are the only elements which may be notably replaced by W. Ti minerals without Nb or Ta do not seem to contain detectable quantities of W; in ilmenite associated with polycrase (Rasvåg, Hidra) and with euxenite (Ljosland 11, Iveland) W could not be shown to be present, while the Nb mineral in both cases contained about 0.05% W. Accordingly the minerals considered here are all Nb–Ta minerals, namely columbite (about 60% Nb + Ta), samarskite–yttrotantalite (about 40% Nb + Ta), fergusonite (about 30% Nb + Ta), euxenite minerals (about 20% Nb + Ta) and ilmenorutile (about 15% Nb + Ta).

The table summarizes the greater part of the results of the W determinations. Many of the specimens listed have been examined by two or more spectrograms.

It is apparent that every one of the mineral species in question may contain W considerably in excess of 1%, and that there is no perceptible correlation between the Nb + Ta contents and the highest W contents of the various minerals. This apparently means that even the specimens richest in W of each species are not by any means "saturated" with W, a conclusion which is also strongly supported by the extreme richness in W of a columbite analyzed by H. BJØRLYKKE as referred to above. Thus it seems probable that no pronounced preference of W for any particular Nb–Ta mineral will be apparent in these deposits. Comparing the various data given in the table, one sees that the most common W concentration is about 0.3%, that the lowest concentrations approach the limit of detection, 0.01%, and that the highest concentrations—as already pointed out—may amount to several per cent. This applies to the Moss district as well as to the Iveland district. (Incidentally the table demonstrates clearly the characteristic paragenetic difference between the two districts.) Although the material examined may be somewhat scarce, the calculated averages given in the table probably give a fairly correct picture. From the above discussion, it is probable that fergusonite from Moss and Iveland and samarskite from Iveland would also exhibit average W contents of the same order of magnitude (0.5–0.6%) if a larger number of specimens were examined. Thus there seems to be no significant difference between the average W contents

Tungsten concentrations in Nb-Ta minerals from two pegmatite-rich Archaean areas in southern Norway.

n = number of specimens.

	Columbite		Samarskite, yttortantalite		Fergusonite		Euxenite, blomstrandine		Ilmeno-rutile	
	W %	n	W %	n	W %	n	W %	n	W %	n
Moss district	0.1	1[1]	0.05	1[5]	0.3	1[12]				
	0.3	5[2]	0.1	1[6]						
	0.5	2[3]	0.3	4[7]						
	2.0	1[4]	0.5	2[8]						
			1.0	1[9]						
			1.5	1[10]						
			2.0	1[11]						
Average	0.5	9	0.6	11						
Iveland district	0.2	2[13]	2.5	3[18]	2.0	1[19]	0.02	3[20]	0.1	1[25]
	0.3	2[14]					0.2	3[21]	0.3	3[26]
	0.5	3[15]					0.3	5[22]	0.5	1[27]
	1.0	2[16]					1.0	1[23]	1.0	1[28]
	1.5	1[17]					3.0	1[24]	2.0	1[29]
Average	0.6	10					0.5	13	0.6	7

Localities

[1] Halvorsrød. [2] Ånnerød, Halvorsrød, Elvestad, Lårbu, Rygge. [3] Karlshus, Skråtorp. [4] Kure. [5] Ånnerød. [6] Aslaktaket. [7] Brøggerhullet, Borheimstaket, Aslaktaket, Ødegårdsletten. [8] Brøggerhullet, Aslaktaket. [9] Ødegårdsletten. [10] Hattevik. [11] Berg. [12] Berg. [13] Tveit 3, Ljosland 1. [14] Tveit. [15] Ljosland 1, Ljosland 3, Eftevann 4. [16] Ljosland 3, Klep. [17] Håverstad. [18] Ivedal 2, Mølland 3, Ljosland 3. [19] Høgetveit. [20] Mølland 10, Ljosland 4, Ljosland 8. [21] Eretveit 1, Mølland 7, Ljosland 11. [22] Tveit 5, Birketveit 1, Støledalen 1, Mølland 7, Landsverk. [23] Mølland 4. [24] Frikstad 7. [25] Eftevann 2. [26] Tjomstøl, Håverstad 4, Lundekleven. [27] Håverstad 1. [28] Tveit 1. [29] Ljosland 4.

For details on the localities, see W. C. BRØGGER, 1906; OLAF ANDERSEN 1931; TOM. F. W. BARTH 1931; H. BJØRLYKKE, 1935 and 1939.

of Nb–Ta minerals from the Moss district and from the Iveland district. This disagrees with the result arrived at by H. BJØRLYKKE (1939, p. 45) that Nb–Ta minerals from Iveland may be distinguished from those from Østfold (Moss district) by their much higher W contents. But BJØRLYKKE had only a small number of analyses of Østfold minerals at his disposal. On the other hand, it is probably true that the *maximum* W contents to be found in Nb–Ta minerals are higher in Iveland than in Østfold.

The data given in the table show that the W content of a Nb–Ta mineral may vary considerably even within a single locality. Thus the high W concentrations seem to be very local, and the supply of W may have varied during the development of the pegmatites. Plotting the observed W concentrations in Iveland on a map of the district, it also appears that the Nb–Ta minerals within certain areas (e.g. part of the farm of Ljosland) are particularly poor in W.

Scattered observations from other districts may be summarized as follows. Euxenite from a granite pegmatite at Spro, Nesodden (Inner Oslofjord) is fairly rich in W (about 1 %). Columbite from the phenacite-bearing pegmatite at Tangen near Kragerø is very poor in W (not definitely observed). The pegmatite is rich in cleavelandite. In this connection it may be mentioned that microlite from the cleavelandite pegmatite at Landås in Iveland is also extremely poor in W. Columbite and ilmenorutile from Ramskjær near Risør both exhibit "normal" W contents (about 0.3 %). Several specimens from the environs of Arendal (samarskite, fergusonite, blomstrandine, euxenite, ilmenorutile) all exhibit low W contents—0.1 % and less. The material, which is admittedly scarce, indicates that the pegmatites of the Arendal district are particularly poor in W. Columbite from a pegmatite at Øvre Gjerstad (some 25 km NW. of Risør) is one of the specimens richest in W examined (about 2 % W). A few specimens of euxenite minerals from Hidra (Hitterø) and other localities near Lindesnes are fairly rich in W (0.3–1 %).

All of the above specimens come from Archaean granite pegmatites. Specimens of koppite from the søvite of the Fen area and of minerals from the Oslo Region pegmatites (polymignite and pyrochlore, Larvik–Stavern) all exhibited very low W contents (far below 0.1 %). W contents of about 1 % were found in fergusonite and samarskite–yttrotantalite from Drag in northern Norway.

In conclusion it appears that most Nb–Ta minerals from Norwegian granite pegmatites contain W in concentrations in the range 0.1–1 %. Lower values are relatively rare, higher not uncommon.

Although ADAMSON and NEUMANN (1952) have identified scheelite in a number of localities, and the occurrence of wolframite and scheelite in the Ørsdalen deposit is well known, tungsten minerals are probably on the whole very scarce in Norway. The total quantity of Nb–Ta minerals in Norwegian deposits must be considerable; possibly even more tungsten is concentrated in them than in scheelite and wolframite. In granite pegmatite wolframite or scheelite would probably not occur unless the coexisting Nb–Ta minerals, if any, were "saturated" with W; no find of wolframite or scheelite in Norwegian granite pegmatite has been reported so far.

References

ADAMSON, OLGE J. & NEUMANN, HENRICH, 1952: Tungsten in Southern Norway. *Norsk Geol. Tidsskr.*, 30, 135.

ANDERSEN, OLAF, 1931: Feltspat II. *Norg. Geol. Unders.*, No. 128 B.

BARTH, TOM. F. W., 1931: Feltspat III. *Norg. Geol. Unders.*, No. 128 B.

BJØRLYKKE, HARALD, 1935: The mineral paragenesis and classification of the granite pegmatites of Iveland, Setesdal, Southern Norway. *Norsk Geol. Tidsskr.*, 14, 211.

— 1939: Feltspat V. *Norg. Geol. Unders.*, No. 154.

BRØGGER, W. C., 1906: Die Mineralien der südnorwegischen Granitpegmatitgänge, I. *Videnskr.-Selsk. Skr.* (*Kristiania*), *Mat.-Naturv. Kl.*, 1906, No. 6.