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Résumé
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Keywords : scheelite, stratiform, anatexis, trace elements, rare-earth elements.

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Mots-clés : scheelite, strates, anatexie, éléments traces, terres rares.

1. INTRODUCTION

Scheelite bearing gneisses are found in the Tanneron Massif, S.E. France (Figure 1). At La Favière mine, they represent an economic concentration. The Tanneron gneisses, partially migmatitic, are made up of a basement, essentially orthogneissic, and a cover, essentially paragneissic, both affected by the same regional metamorphic event presumably of Caledonian age (Crevola, 1977). Scheelite bearing gneisses occur at several stratigraphic levels in the cover and in the basement as well. These deposits may be called stratiform as the ore bodies occur only in calc-silicate gneisses. Similar occurrences have been found elsewhere in the crystalline basement of southern France (Boyer et Routhier, 1974 ; Béziat et Tollon, 1976).

Stratiform scheelite deposits seem to be widespread around the world. They are usually interpreted in terms of a preconcentration in sediment piles linked to basic volcanism and a later dissolution and redeposition in favourable beds during regional metamorphism (Maucher, 1976 ; Denisenko and Rundkvist, 1978 ; Plimer, 1980). Remobilisation of ancient scheelite skarns can also be hypothesised. In this paper we propose an alternative genetic model which we shall call "peri-anatectic" model. It is based on the assumption that tungsten, and other elements, are introduced during metamorphism by fluids expelled forth from the anatexis isograd. Precipitation of scheelite and other chemical exchanges occur when these fluids cross calc-silicate gneisses during their travel through the rocks. This process may be considered as infiltration metasomatism like the one giving rise to skarns. The La Favière deposit constitutes a favourable case since its geological context lacks any plutonic or basic volcanogenic features.

2. GEOLOGICAL SETTING

The main scheelite bearing calc-silicate gneiss lenses occur in series of micaceous gneisses in the area of La Favière (Aicard *et al.*, 1971). Scattered scheelite showings are found in plagioclase gneisses elsewhere (Figure 1). The entire mineralized district forms a broad elongated area stretching over a distance of 11 km. This area runs roughly parallel to the basement-cover boundary and extends outside the map of figure 1 in a NNE direction. A small occurrence appears in the orthogneiss of Bois de Bagnols located in the western margin of the Reyran graben.

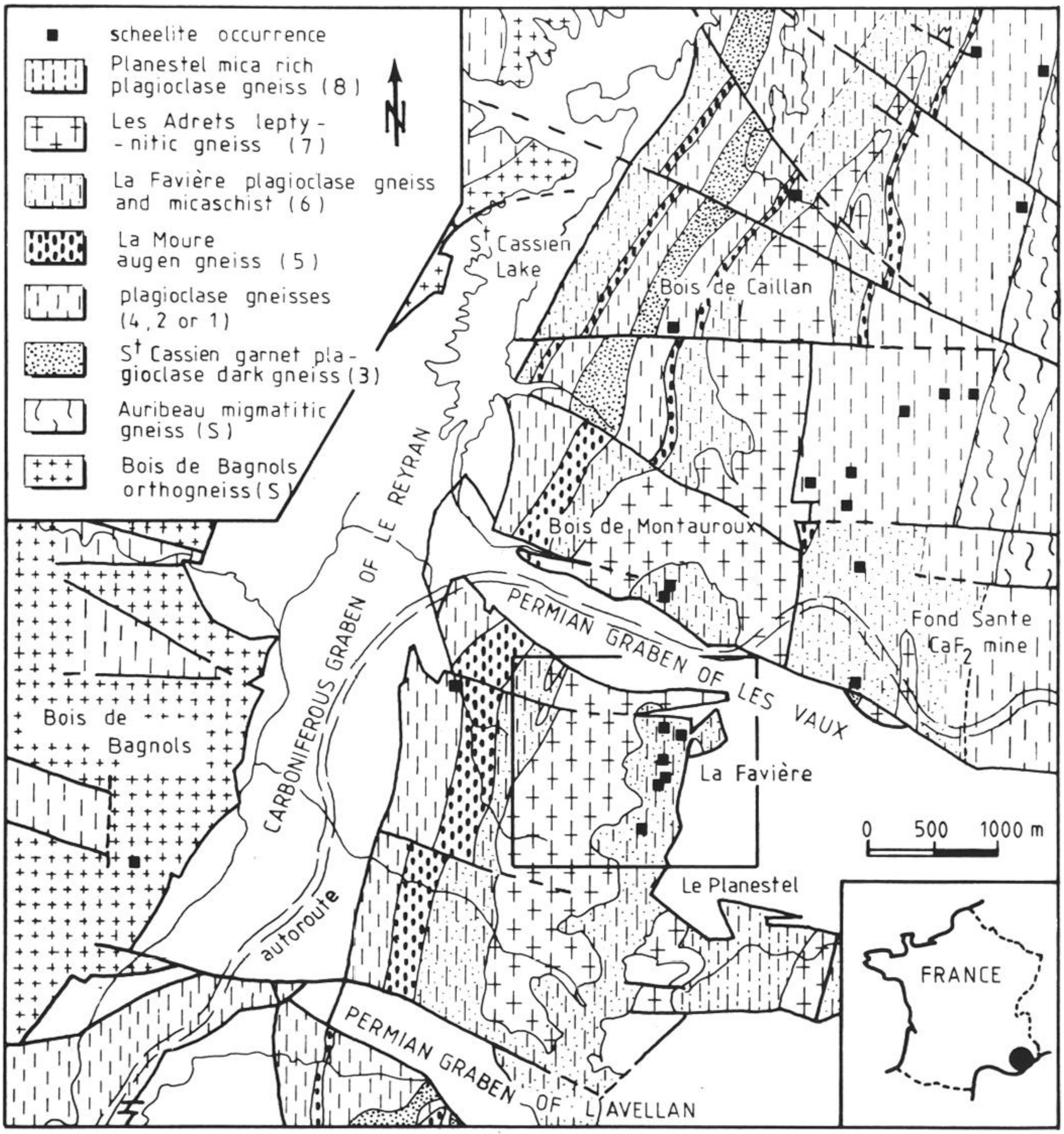

FIG. 1. — *Geological map of the central part of the Tanneron massif.* Inside frame indicates figure 4.
Carte géologique de la partie centrale du massif du Tanneron. L'encadré désigne la figure 4.

A broad recognition of the gneissic formations was made by Bordet (1961). More detailed studies can be found in Orsini (1968) for the southern part of the area and in Crevola (1977) for the eastern part. New data and mapping are still in progress (Crevola, in preparation). A tentative lithostratigraphic column is given in figure 2. The formations are numbered from 0 (base) to 8 (top). Most of the formations are made of monotonous, more or less micaceous plagioclase gneisses. However, particular lithologic levels such as 3, 5 and 7 are more characteristic and easily mapable. Their identification makes the reconstructions of the stratigraphic column possible. The limit between basement and cover is given as the contact between 0 and 1. This contact is visible in the eastern part of the map of figure 1 but not on the western part where it is covered up by the sediments of the Reyran graben.

Three main folding phases have been recognized. The first phase P1 cannot be observed at cartographic scale. It resulted in a generalized syn-metamorphic foliation. The two subsequent phases P2 and P3 account for the elongated arrangement of the formations in parallel NNE bands (Figure 1). P2 are recumbent kilometric folds. The associated deformation is of ''rheid fold'' type which, through extensive blastomylonitization caused a narrowing of the limbs of the folds and a thickening of the hinge zones. P3 are concentric folds which range in scale from several kilometers to a few decimeters and largely determine the general structure of the area. The southwards plunging axes of P2 and P3 are nearly parallel and their orientation varies between N and NNE.

Two main late faulting phases may also be distinguished : the former (N to NNE), of Stephanian age, induced the formation of the Rey-

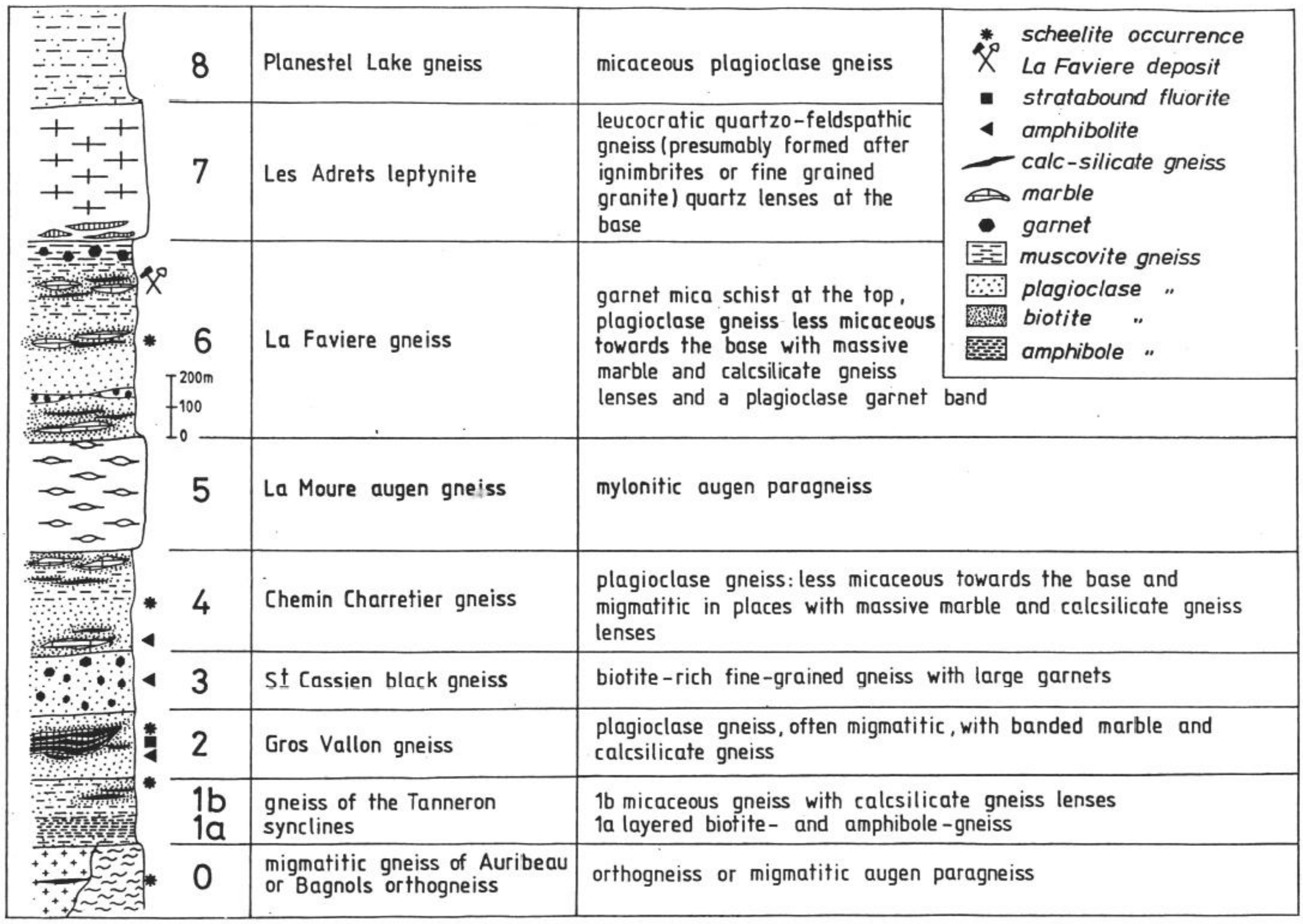

FIG. 2. — *Tentative lithostratigraphic column of the gneisses of the central part of the Tanneron massif.*
Colonne lithostratigraphique proposée pour les gneiss de la partie centrale du massif du Tanneron.

ran graben ; the latter (ESE to SE), of Permian age, formed the Avellan graben and the Les Vaux graben. These vertical movements may be very important inside the gneissic cover as they give rise to adjoining fault blocks having different structures.

Migmatization is widely developed in the basement whereas it appears only sporadically in the cover. Migmatitic features in the cover increase to the east towards the basement-cover contact (Figure 1) but are also found to the west in several levels such as 2 and 7 and to a lesser extent, in levels 4, 5 and 6 (Figure 2). Migmatitic features are defined here as fused rocks, quartzo-feldspathic veins or bands (leucosomes), small bodies of anatectic granitoïd and pegmatite-aplite mixed veins and dykes.

Concerning the chronological relationships between migmatitic features and folding phases, field investigations show that the mixed pegmatite-aplite veins are of various ages. Some are discordant on P1 foliation but are folded and blastomylonitized by phase P2. Post P2 pegmatite-aplite veins and even post P3 veins (outside perimeter of figure 1) have been found. These late veins are conspicuous and restricted to specific areas, compared to the pre P2 pegmatite-aplites which are widespread. The small bodies of anatectic granitoïd are all of pre P2 origin.

3. MODE OF TUNGSTEN OCCURRENCE

While many rock types are present in the studied area, tungsten concentrations are restricted to calc-silicate gneiss. Scheelite is the only tungsten bearing mineral. Generally speaking, there are no indications of quartz-scheelite vein-type or some other granite related mineralization. However, stratiform fluorite showings have been found north of figure 1 (Crevola et Sonnet, 1984). They do not seem to be related to the scheelite deposition.

Calc-silicate gneiss and marble form lens shaped bodies which often occur together as bundles in the plagioclase gneiss (Figure 3*a*). The lenses are systematically surrounded by a shell of fine grained dark biotite-rich plagioclase gneiss. Marble beds are commonly associated with the calc-silicate gneisses. They occur either as interbedded bands or as separate levels. Tungsten occurrences take the form of bodies of disseminated scheelite whose disposition in the barren calc-silicate gneiss can be seen in favourable cases as discordant on the bedding. The ore grade is constant (5 to 6 wt.% WO_3) and there is no transitional decrease in the abundance of scheelite towards the barren gneiss. Mixed marble-calc-silicate gneiss ore is sometimes encountered, but this is a result of a tectonic brecchiation due to the marble incompetency. The mineralization is not controlled by P2

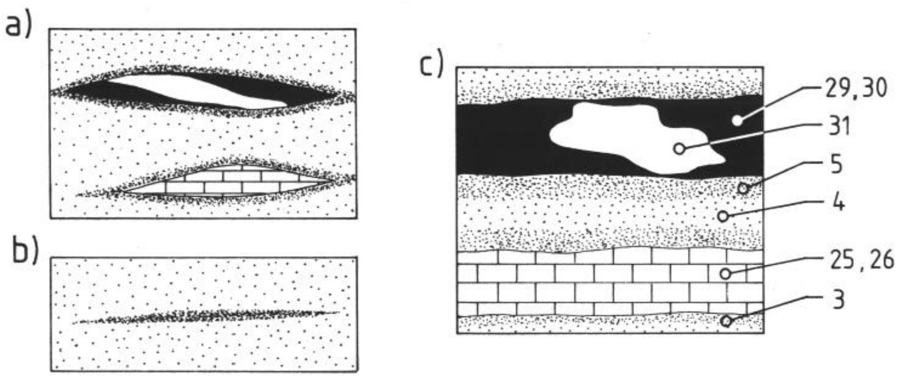

FIG. 3. — *Morphological relationships between calc-silicate lenses and their environment.* (a) usual situation : stretched lenses in plagioclase gneiss surrounded by a shell of biotite-rich plagioclase gneiss. Scheelite enriched bodies cross-cut the foliation. (b) Lenses are often devoid of their central part of calc-silicate gneiss and marble. (c) Reconstruction of the original calc-silicates mineralised horizon before phase P2 ; numbered circles refer to samples of tables I and III taken at La Favière mine.

Relations morphologiques entre les lentilles à silicates calciques et leur encaissant. Les cercles numérotés réfèrent aux échantillons des analyses des tableaux I et III prélevés sur le site de la mine de La Favière.

or P3 folds, nor by the fracture pattern. The crystallization of scheelite preceded phase P2, for some scheelite seams are clearly folded and blastomylonitized by P2.

4. STRUCTURAL SETTING OF THE ORE BODIES

Figure 4 presents an enlarged map of La Favière mine area and a cross section in the area north of it. The mine is located in the La Favière gneiss formation in the eastern limb of a P3 syncline. This syncline refolds a recumbent P2 syncline whose hinge zone consists of leptynitic gneiss. Broadly speaking, the ore bodies have a horizontal disposition slightly affected by P3 undulations. However, upon closer inspection, their structure is much more complicated as it results from the stacking up of small recumbent folds due to the proximity of a P2 hinge zone. This tectonic thickening of the calc-silicate gneiss levels contributed to the formation of an economic sized deposit. Furthermore, numerous vertical faults related to the grabens cut the deposit in small fault blocks ranging from a few meters to a few decimeters in size.

Outside of the La Favière area, the marble and calc-silicate gneiss occur mainly as small sized lenses. The origin of the lenticular shape is thought to be due to boudinage (Figure 3). Very often the local tectonic stretching is such that known bundles of calc-silicate and marbles lenses several meters thick reduce down to a few ribbons measuring only a few centimeters in width. The central part of the ribbons generally lacks any trace of marble which is thought to have been squeezed out. In many cases, the calc-silicate gneiss is also swept away and only the fine grained dark biotite-rich plagioclase shell remains (Figure 3*b*). These phenomena have been observed for barren as well as for mineralized calc-silicate gneisses.

5. PETROGRAPHY OF THE PLAGIOCLASE GNEISSES AND CONDITION OF METAMORPHISM

Detailed petrographic investigation has been performed by one of the authors (Crevola, 1977), and additional petrographic investigation and geothermobarometry is in preparation (Uchida, personal communication). Only the most essential features will be described in this paper.

Virtually all the gneisses consist of a fine to medium (0.3-2 mm) grained mixture of quartz, plagioclase and biotite. The plagioclase composition lies between mol.% An_{10} and An_{45}. Biotite compositions are given by $0.53 < FM < 0.70$ (FM = Fe/Fe + Mg). Some of the plagioclase gneisses contain garnet for which FM lies between 0.85 and 0.95. Spessartine component is usually low, but in some cases may rise up to 30 mol.%. The grossularite component is even lower but may rise up to 10 mol.%. Sillimanite is frequently present. Kyanite is very rare. Some levels contain muscovite as a primary constituent. Muscovite associated with blastomylonitization is widespread. Alkali feldspar is common but appears very rarely in association with sillimanite and only then is the rock devoid of muscovite.

The proportions of these minerals are variable, thereby accounting for the colour and part of the texture of the rock. Garnet forms porphyroblasts, especially in the St-Cassien black gneisses 3 and at the top of La Favière formation 6. In La Moure augen gneiss, plagioclase may appear as eyes associated with quartz and alkali feldspar. Late sillimanite and/or muscovite are common on shear surfaces associated with the blastomylonitization. Accessory minerals are : zircon, apatite, occasionally tourmaline.

The main mineralogical assemblages are thus : (i) quartz-plagioclase-biotite ± garnet ± sillimanite ± muscovite ; (ii) quartz-plagioclase-biotite ± garnet ± alkali feldspar ± muscovite ; and very rarely (iii) quartz-plagioclase-biotite-garnet-sillimanite-alkali feldspar. We are thus dealing with the amphibolite facies wherein the formations lie mainly in the sillimanite zone. Only in places was the sillimanite alkali-feldspar isograd reached. Geothermobarometer anorthite = grossularite + sillimanite (or kyanite) + quartz (Ghent, 1976 ; Ghent *et al.*, 1979), along with geothermometer biotite-garnet (Thompson, 1976 ; Ferry and Spear, 1978) were used to estimate the (P,T) maxima as $550°C < T < 700°C$; $3\ kbar < P < 6\ kbar$. The maximum values obtained (700°C and 6 kbar) probably represent the best values because possible ionic exchange (Fe $\gtrless$ Mg) and reequilibration during retrogressive metamorphism lead to an underes-

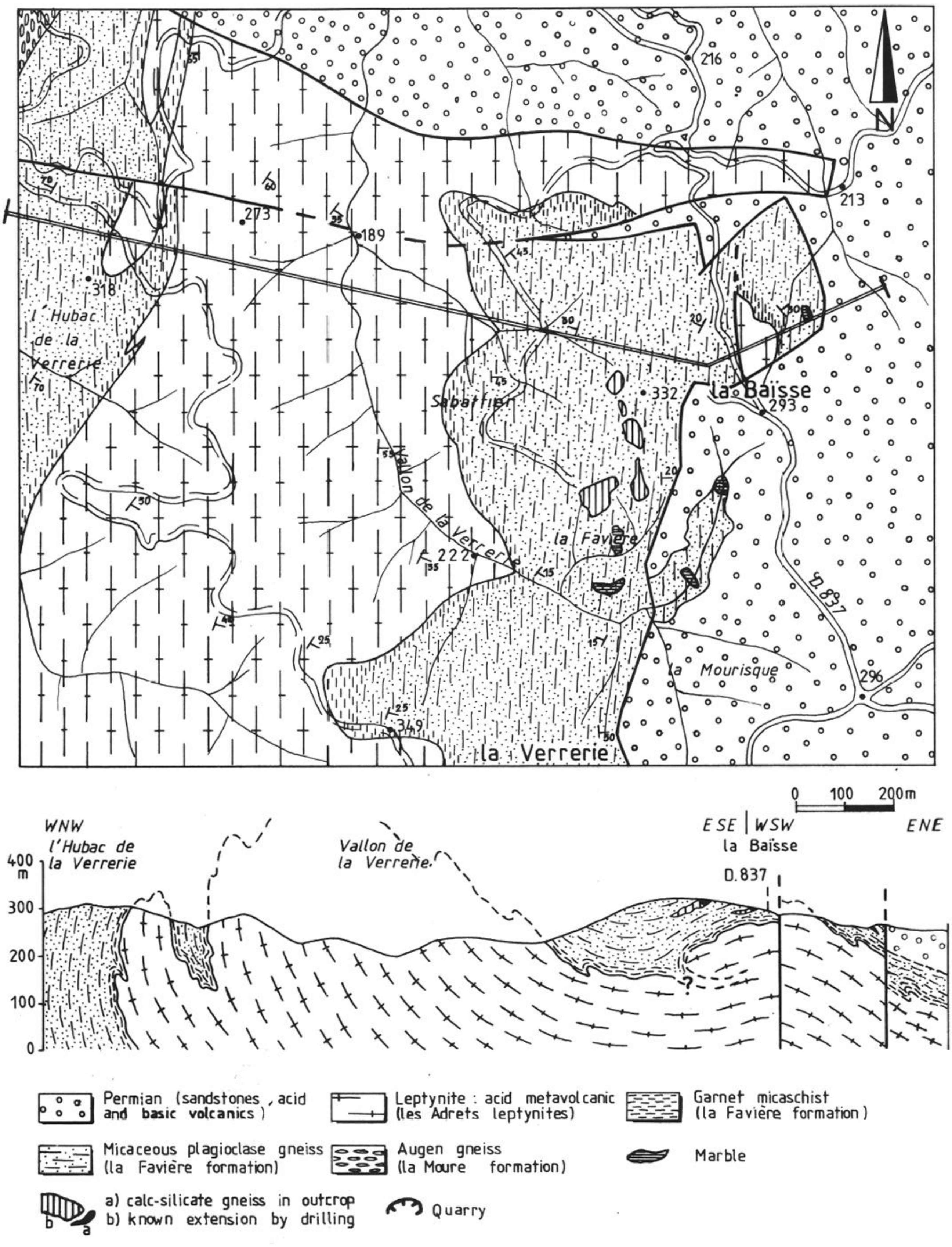

FIG. 4. — *Geological map of La Favière area*. The double line gives the direction of the cross-section.
Carte géologique de la zone de La Favière. La ligne à double trait donne la direction de la coupe.

timation of the temperature and of the pressure. For 6 kbar, the minimum melting T for granitic systems is 640°C (Tuttle and Bowen, 1958). Therefore migmatic conditions could have been attained in certain area.

6. PETROGRAPHY OF THE CALC-SILICATE GNEISSES

As seen above, the calc-silicate gneiss lenses are surrounded by a shell of fine grained dark biotite-rich plagioclase gneiss. The mineralogical assemblage in the shell is, in order of decreasing abundance : plagioclase (An_{20}), biotite, quartz, titanite and apatite. The FM ratio (FM = Fe + Mn/Fe + Mn + Mg) for biotite is lower around mineralized lenses than around barren ones (respectively 0.44 and 0.55). The assemblage in the barren calc-silicate gneiss is, once again in order of decreasing abundance : plagioclase (An_{80}), Ca-pyroxene (Di_{50}), quartz, titanite, apatite and sulphides (pyrrhotite and arsenopyrite). Aside from the introduction of scheelite, there is no significant mineralogical difference between mineralized and barren calc-silicate gneiss. However, chemical changes occur in the plagioclase and the pyroxene. The compositions become variable within a single grain. Plagioclase compositions are less anorthitic (down to An_{25} instead of An_{80}) whereas pyroxene compositions are more diopsidic (up to Di_{90} instead of Di_{50}).

Thus in the mineralized area, there is both a loss of calcium in the plagioclase and of iron in the pyroxene and the biotite. The metasomatic replacement phenomena are somewhat incomplete as inferred by variable compositions within a single grain. The texture of the rock is usually fine-grained (0.3-1 mm), but when mineralized in scheelite, the grain size increases notably (several mm) and the metamorphic foliation is lost. The scheelite grains (typically 5 mm) exhibit fragmentation and wavy extinction, probably inherited from phase P2.

From this petrographic investigation, we reach the conclusion that the scheelite bearing rocks were presumably formed by metasomatic transformation of calc-silicate gneiss. But the hypothesis of a formation at the expense of marble beds cannot be ruled out at this stage of the study.

7. MAJOR ELEMENTS GEOCHEMISTRY

Analytical results presented here are restricted to the La Favière formation as it contains the main scheelite bearing calc-silicate gneiss deposits in the area. Geochemical investigation on other formations also enclosing scheelite showings (units 4, 2, 1a and basement) is still in progress and is broadly leading towards similar conclusions. Analyses of the La Favière gneiss samples are given in tables I and II. Oxides were measured by XRF except Na_2O and MgO for which AA and DCP were used respectively. The origins of the samples are shown on figures 3 and 5.

	1	2	3	4	5	6	7	8
SiO_2	65.10	69.80	69.25	65.91	75.47	74.20	67.09	59.32
TiO_2	0.82	0.79	0.86	0.82	0.63	0.48	0.66	0.92
Al_2O_3	15.40	14.45	13.05	16.13	11.90	11.80	15.74	22.07
Fe_2O_3	1.75	1.29	4.88	5.91	3.23	1.75	6.45	5.69
FeO	4.66	3.61	-	-	-	1.65	-	-
MnO	0.09	0.05	0.09	0.60	0.05	0.03	0.13	0.09
MgO	2.45	2.28	1.81	2.31	0.86	1.21	1.08	1.12
CaO	1.52	1.02	1.71	0.33	0.37	0.24	0.11	0.06
Na_2O	2.90	2.75	2.33	1.95	2.13	1.07	0.98	0.43
K_2O	3.24	2.70	2.42	2.98	2.38	3.50	3.80	5.40
P_2O_5	tr	0.23	0.28	0.18	0.16	tr	0.18	0.16
l.i.	1.66	1.85	1.87	3.13	1.66	2.59	2.61	4.43
Total	99.59	100.52	98.55	100.25	98.84	98.52	98.83	99.69
Be			<1	<1	<1		<1	<1
B			56	62	43		54	38
Sc			11	15.80	8.30		13.90	16.90
V			90	137	58		98	141
Cr			64	95	58		434	385
Co			12	14.20	7.40		15.70	10.30
Cu			<10	54	<10		<10	20
Rb			105	105	89		148	195
Sr			138	72	69		47	57
Mo			<3	<3	<3		<3	<3
Ag			<1	<1	<1		<1	<1
Sn			9	8	<5		10	8
Ba			453	670	559		603	687
Hf			8.70	5.70	8.70		5.90	5
Ta			1.25	1.14	1.22		1.18	1.75
W			<2	<2	14		-	-
Th			14.60	12	17		17.40	19.20
U			4.80	3.20	4		5.50	5.20
La			38.90	37.20	46.50		44.50	59.10
Ce			82	80	97		97	123
Nd			38	36	41		42.90	54
Sm			7.19	7.10	7.28		8.40	9.80
Eu			1.28	1.40	1.10		1.24	1.65
Gd			-	-	-		-	-
Tb			1.01	1.05	0.96		1.21	1.15
Yb			3.35	3.56	3.13		3.61	3.07
Lu			0.60	0.54	0.55		0.61	0.53

TABLE I. — *Major (%) and trace (ppm) elements analysis of samples of plagioclase gneiss.*

Analyse des éléments majeurs et en trace dans les gneiss plagioclasiques.

	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SiO_2	62.53	66.49	58.16	67.44	69.74	71.35	65.91	66.21	61.54	64.43	62.49	59.50	63.19	64.86	64.87	68.41
TiO_2	0.67	0.75	0.91	0.82	0.64	0.67	0.78	0.85	0.82	0.81	0.94	0.71	0.67	0.81	0.84	0.66
Al_2O_3	14.02	15.09	15.47	15.64	13.76	13.49	14.98	13.72	14.92	14.28	15.71	14.64	15.29	13.99	14.04	14.78
Fe_2O_3	3.98	4.57	5.54	5.69	4.04	3.79	5.80	6.10	6.12	6.08	7.65	6.34	5.42	5.90	6.46	4.73
FeO																
MnO	0.12	0.05	0.14	0.09	0.09	0.14	0.09	0.09	0.10	0.10	0.07	0.12	0.09	0.09	0.09	0.08
MgO	2.60	2.85	2.38	2.09	1.64	1.70	2.39	3.00	3.05	3.15	3.13	3.74	2.07	2.84	3.12	2.30
CaO	4.40	3.55	4.23	0.74	0.92	0.83	0.88	1.00	2.05	1.30	0.21	4.73	2.38	0.80	1.18	0.69
Na_2O	2.39	3.40	1.80	3.15	3.43	1.88	3.24	2.17	3.12	2.92	1.99	3.13	3.13	2.00	2.40	2.55
K_2O	2.07	1.63	1.82	2.30	3.16	2.53	2.59	2.58	4.69	3.49	3.34	1.62	2.56	3.09	2.23	2.40
P_2O_5	0.16	0.15	-	0.21	0.16	0.17	-	0.10	0.20	0.19	0.04	0.24	0.31	0.18	0.16	0.09
l.i.	5.69	1.32	7.55	2.33	1.55	3.01	1.32	1.61	1.26	1.45	1.73	3.36	2.96	1.90	2.11	2.94
Total	98.63	99.85	98.00	100.50	99.13	99.56	97.98	97.43	97.87	98.20	97.30	98.13	98.07	96.46	97.50	99.63
Rb	99	84	104	100	94	88	102	113	164	148	118		107	152	100	107
Sr	64	176	85	109	191	129	158	167	307	282	142	333	259	150	205	164
Ba	490	550	800	770	1090	770	780	960	1120	851	2456	500	756	841	771	830
Ce	136	133	186	179	220	181	163	230	232	250	454	119	188	210	170	192

TABLE II. — *Major and trace elements analysis of samples of plagioclase gneiss.*
Analyse des éléments majeurs et en trace dans les gneiss plagioclasiques.

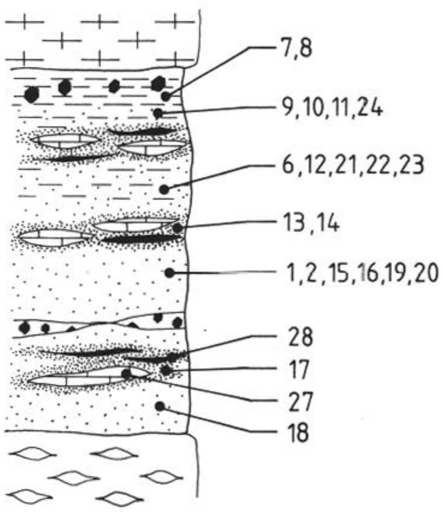

FIG. 5. — *Lithostratigraphic column of the La Favière formation indicating approximate location of the samples of tables I, II and III taken outside the La Favière mine.*

Colonne stratigraphique de la formation de La Favière indiquant approximativement la localisation des échantillons des tableaux I, II et III prélevés en dehors du site de la mine de La Favière.

Analyses of gneisses, excluding calc-silicate gneisses are plotted in a SiO_2-Al_2O_3 (wt.%) diagram in figure 6. The slightly negative correlation indicates a geochemical homogeneity which suggests that deposition occurred during a uniform sedimentary sequence. In order to appreciate the proportion of feldspar and clay which were originally present during sedimentation, the same analyses have been plotted in a

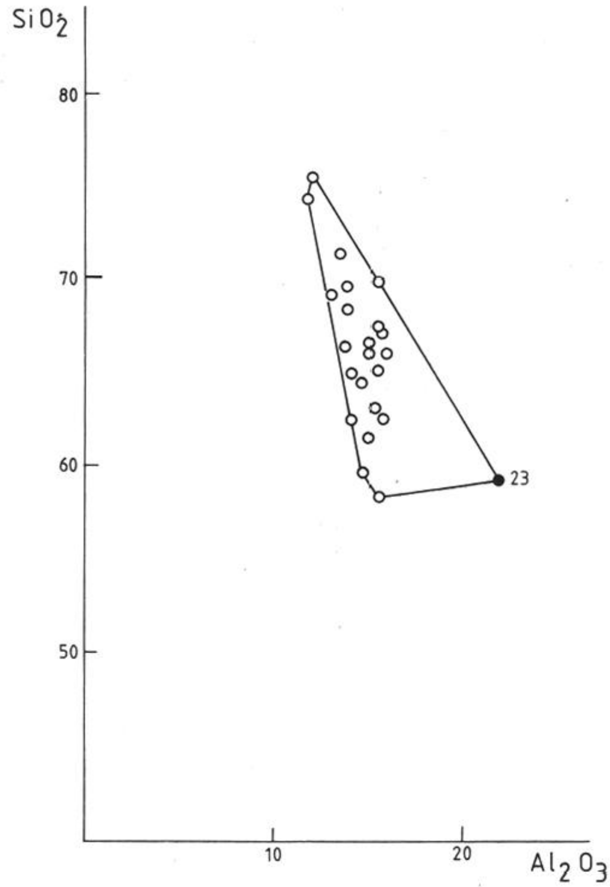

FIG. 6. — *SiO_2-Al_2O_3 (wt. %) plot of plagioclase gneiss analyses.* Open circles stand for analyses 1 to 23 of tables I and II. Only point 23 (Table II) is numbered.

Diagramme SiO_2-Al_2O_3 (% poids) des gneiss plagioclasiques de La Favière. Les cercles ouverts représentent les analyses 1 à 23 des tableaux I et II. Seule l'analyse 23 (Tableau II) est numérotée.

(Na_2O + 31/47 K_2O)-Al_2O_3 (wt.%) diagram (Figure 7). This diagram permits one to estimate the relative proportion of alumina bound to detritic feldspar versus the non-feldspathic alumina bound to clay minerals and micas. It is thus possible to discriminate between metasedimentary rocks belonging to the fields of arkoses, lithic sandstones, greywackes or shales (Fonteilles, 1976). All rock compositions fall in the greywackes field, except 23, which fall into the field of shales.

The analysed rocks including calc-silicate gneisses and marbles are plotted in a CaO-K_2O-Na_2O (wt.%) triangle (Figure 8). The CaO poor boundary of the cloud of representative points can be drawn as a line joining the K_2O apex to point A on the Na_2O-CaO side. This point corresponds to a plagioclase containing 16 mol.% anorthite. This composition is thought to represent the lowest anorthite content in the detritic plagioclase.

Rock compositions lying on this line may be interpreted as mixture of a clay-rich (shale) with a plagioclase-rich component (greywacke). Other such lines can be drawn from the K_2O apex through the different representative points, each giving somewhat richer plagioclase compositions on the Na_2O-CaO side (not shown on figure 8). This variability of the inferred detritic plagioclase can be accounted for by early diagenetic and/or metamorphic albitisation. Another ill-defined trend can be materialized by the line joining the CaO apex to the point B. Along this line, rock compositions may be interpreted as resulting from a depositional mixture of plagioclase-rich greywackes and free carbonates. Calc-silicate gneisses lie near the CaO corner but still follow this trend.

The original sedimentary sequence may thus be regarded as a shale-sandstone flysch sequence laid down by turbiding currents and containing sparse intercalations of shales, carbonates and intermediate terms resulting from the mixing of greywacke and free carbonate (the calc-silicate gneisses).

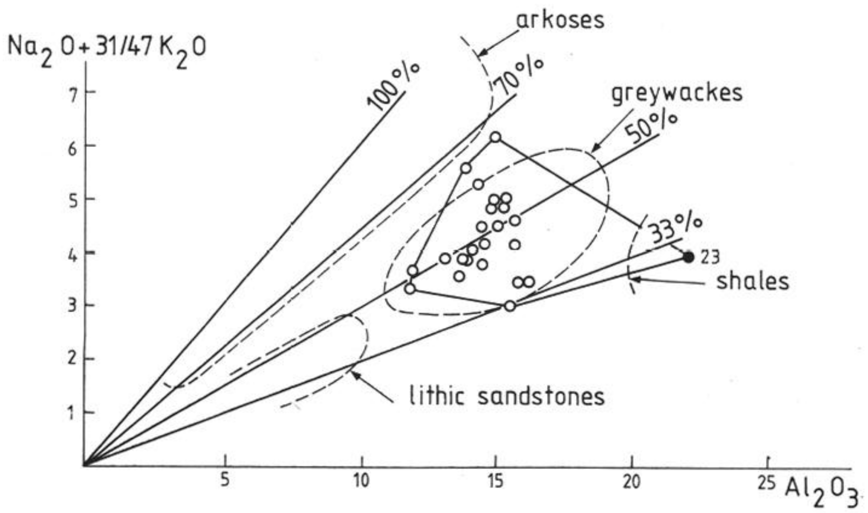

FIG. 7. — *Na_2O + 31/47 K_2O-Al_2O_3 (wt. %) plot of plagioclase gneiss analyses.* Open circles represent analyses 1 to 23 (Tables I and II). Only 23 (Table II) is numbered. The 31/47 factor is the ratio between the molecular weights of Na_2O and K_2O. This ratio is used to convert K_2O wt. % into fictive Na_2O wt. % with conservation of the number of atomes. The straight line 100 % means that Al is linked to (Na+K) with a ratio of 1:1, *i.e.* all the Al is supplied by the feldspar fraction of the rock according to (Na,K)$AlSi_3O_8$. Line 33 % means that Al is bound to (Na+K) with a ratio 3:1 which corresponds to Al in pyllites. Lines 70 % and 50 % are intermediate.

Diagramme Na_2O + 31/47 K_2O-Al_2O_3 (% poids). Les cercles ouverts représentent les analyses 1 à 23 des tableaux I et II. Seule l'analyse 23 (Tableau II) est numérotée.

8. TRACE ELEMENTS GEOCHEMISTRY (Tables I, II and III)

Sc, Cr, Co, Hf, Ta, Th, U, W and R.E.E. have been analysed by neutron activation, WO_3 in the ore (n° 31, table III) by X-ray fluorescence, Be, B, Ag, Sn, Mo by arc spectrometry and Rb, Sr, Ba, V, Cu by spark spectrometry.

1) Rare earth elements : figure 9*b* shows the

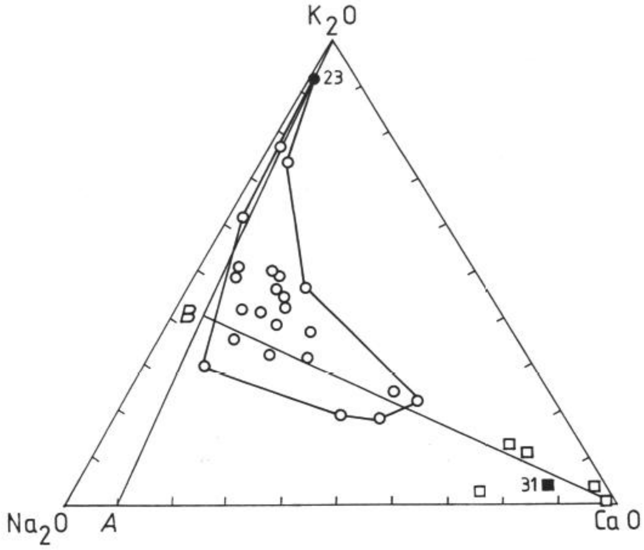

FIG. 8. — *K_2O-Na_2O-CaO (wt. %) plot of plagioclase gneiss (open circles : analyses 1 to 23, tables I and II) marble and calc-silicate gneiss (open squares : analyses 25 to 31, table II).* Solid square 31 is the mineralized calc-silicate gneiss, while solid circle 23 stands for the most shaly gneiss of the series.

Diagramme K_2O-Na_2O-CaO (% poids) des gneiss de La Favière (cercles ouverts : analyses 1 à 23, tableaux I et II), marbres et gneiss à silicates calciques (carrés ouverts : analyses 25 à 31, tableau II). Le carré plein 31 est le gneiss à silicates calciques minéralisé, tandis que le cercle plein 23 est le gneiss le plus proche des shales dans la série.

	25	26	27	28	29	30	31
SiO_2	3.32	30.06	6.94	56.23	47.68	58.69	52.18
TiO_2	0.07	0.36	0.09	0.76	0.72	0.85	0.22
Al_2O_3	0.89	4.87	1.11	15.20	21.91	14.80	12.26
Fe_2O_3	0.74	1.68	0.65	6.89	5.02	4.17	6.03
FeO							
MnO	0.05	0.07	0.03	0.16	0.23	0.08	0.26
MgO	1.75	1.12	1.52	2.88	3.76	1.82	2.03
CaO	51.00	27.72	46.21	10.99	13.64	8.72	12.74
Na_2O	tr	0.97	0.35	1.81	1.76	2.67	1.54
K_2O	0.15	0.95	0.24	1.89	2.09	0.44	0.72
P_2O_5	0.31	0.13	0.29	0.44	0.25	0.24	0.22
l.i.	41.47	24.57	37.71	1.68	2.11	5.33	1.94
WO_3							5.74
Total	99.75	92.50	95.14	98.93	99.17	97.81	95.88
Be	<1	<1	<1	<1	17	25	46
B	<5	<5	<5	99	26	47	9
Sc	1.85	5.05	1.94	13.7	12.2	13	2.95
V	75	81	91	134	149	118	144
Cr	7	27	22	73	59	81	15
Co	1.08	4	1.81	38.7	4	4.5	41
Cu	<10	>150	<10	39	16	121	17
Rb	28	42	20	106	51	13	25
Sr	3415	1641	6190	878	1012	984	608
Mo	<3	<3	<3	<3	<3	<3	3
Ag	<1	1.2	<1	<1	<1	<1	<1
Sn	<5	<5	<5	47	116	154	16
Ba	71	1016	1173	912	518	270	347
Hf	0.33	1.81	0.59	4.36	3.84	5.8	0.68
Ta	0.07	0.35	0.12	0.94	0.85	1.07	7.3
W	3	34	<2	4	200	10	-
Th	1.06	3.52	1.48	9.7	9.1	12.5	2.08
U	1.6	3.5	4.5	5.4	4.3	6.0	-
La	6.1	7.3	9.2	31.1	27.1	38.3	11.1
Ce	11.2	16.6	15.2	67	54	79	16.1
Nd	5.5	9	7.8	30	25	37	8
Sm	1.1	2.04	1.29	6.17	4.87	6.8	-
Eu	0.27	0.50	0.29	1.46	1.08	1.74	1.08
Gd	-	-	-	-	-	-	-
Tb	0.174	0.35	0.20	0.91	0.69	0.9	0.25
Yb	0.57	1.39	0.69	2.97	2.20	3.02	0.72
Lu	0.11	0.23	0.12	0.59	0.38	0.51	-

TABLE III. — *Major and trace elements analysis of samples of calc-silicate gneiss and marble.*

Analyse des éléments majeurs et en trace dans les gneiss à silicates calciques et dans les marbres.

R.E.E. spectrum in calc-silicate gneisses normalized with respect to the NASC standard (North American Shale Composite, Wildeman and Haskin, 1973). The mineralized calc-silicate gneiss 31 shows a strong positive anomaly for Eu while all the other R.E.E. are strongly depressed with respect to their counterparts in the barren calc-silicate gneiss (28, 29, 30). Figure 9*a* shows the R.E.E. spectrum in the plagioclase gneiss of the La Favière formation and figure 9*c* in the marble. Comparison of figures 9*b* and 9*c* reveals a same general level for R.E.E., except for Eu in the marble and the mineralized calc-silicate gneiss. Comparison of figures 9*b* and 9*a* reveals a same general level for R.E.E. in the plagioclase gneiss and the barren calc-silicate gneiss, except a slight positive anomaly in Eu for the latter.

2) La, Th, Hf, Ta : figure 10 shows a linear correlation, in logarithmic coordinates, between La and Th in the calc-silicate gneiss and the marble. If La is strongly depressed in the mineralized calc-silicate gneiss 31, the same holds true for Th ; levels for La and Th are approximately equivalent to those in the marble. Figure 11 also shows a linear correlation between Hf and Th with a strong depressed value for Hf in the mineralized calc-silicate gneiss. Figure 12 shows, in contrast, that the mineralized calc-silicate gneiss is richer in Ta than is the barren one.

3) W, Be : no correlation diagram can be constructed on the basis of analytical data for W and Be. One may nevertheless observe that in the mineralized areas the marble is enriched in W (34 ppm for sample 26), while the regional geochemical value for marble is below 2 to 3 ppm (samples 25 and 27). The shells of biotitic gneiss surrounding the mineralized calc-

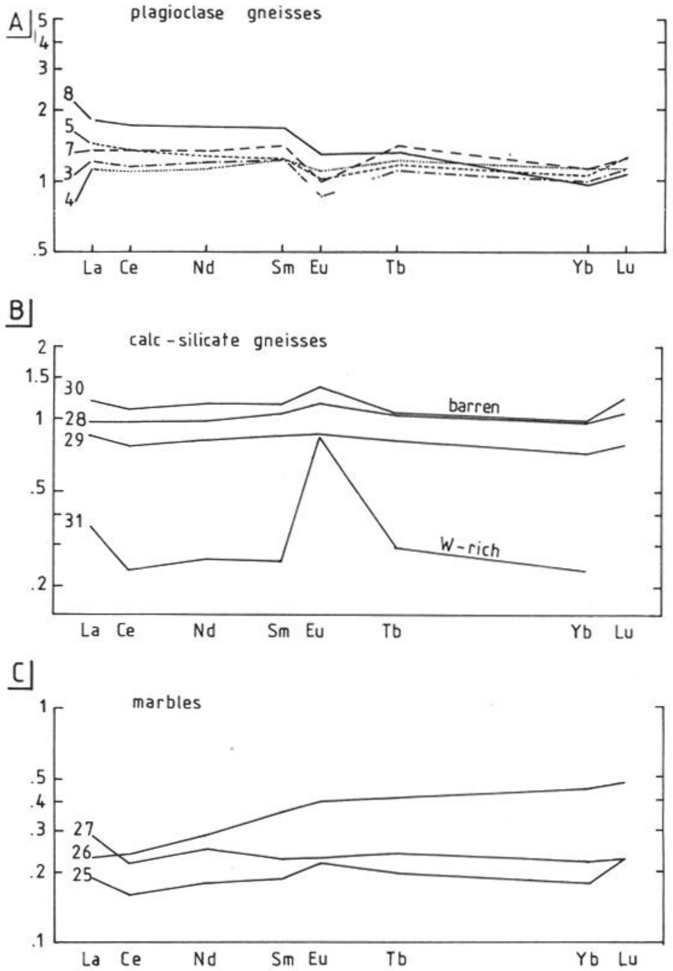

FIG. 9. — *Rare earth distribution (logarithmic ordinate) relative to the North American Shale Composite (NASC) :* (a) plagioclase gneiss (Table I) ; (b) calc-silicate gneiss (Table III) ; (c) marble (Table III).

Distribution des terres rares (ordonnée logarithmique) normées par rapport au North American Shale Composite (NASC) : (a) gneiss plagioclasiques (Tableau I) ; (b) gneiss à silicates calciques (Tableau III) ; (c) marbres (Tableau III).

silicate gneiss lenses is much richer in W (14 ppm instead of 2 ppm for the regional level for biotitic gneiss). The barren calc-silicate gneiss is also richer in W (200 and 10 ppm respectively for samples 29 and 30, instead of 4 ppm or less for the regional level for calc-silicate gneiss 28). Be is high in the barren calc-silicate gneiss lenses occurring in the vicinity of the ore bodies (17 to 25 ppm, samples 29 and 30) while it is less than 1 ppm for the regional level.

4) Ag, Hg, Sb, Mn : Hg and Sb are below the

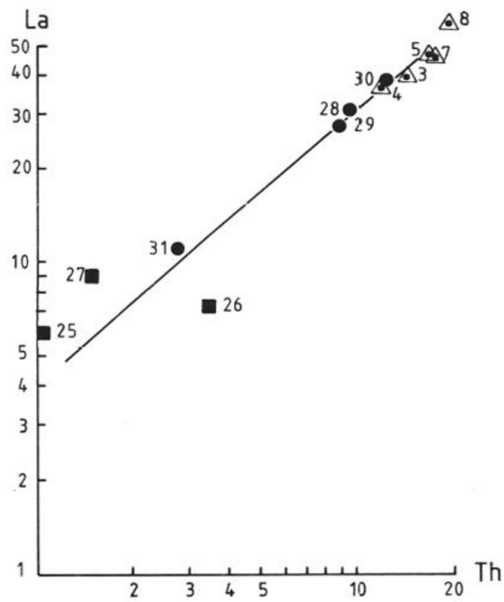

FIG. 10. — *Bi-logarithmic plot (ppm) La-Th for the marble (squares) and calc-silicate gneiss (circles) (Table III) and for the plagioclase gneiss (triangles) (Table I).*

Diagramme bi-logarithmique (ppm) La-Th relatif aux marbres (carrés) et gneiss à silicates calciques (cercles) (Tableau III) et des gneiss plagioclasiques (triangles) (Tableau I).

limit of detection in all the rocks analyzed. Mn and Ag are never above the regional level. This may be considered as an indication of the negligible rôle of volcanogenic events in the sequence.

5) Mo and Sn are very low in contrast to other known stratabound scheelite occurrences (see for example Tweto, 1960, and Skaarup, 1974).

Considering the results of the trace elements analysis, one may propose two interpretations as to their behaviour during the mineralizing process : (i) introduction of W in the calc-silicate gneiss was accompanied by introduction of Be and Ta and by a removal of R.E.E. except Eu ; (ii) introduction of W was accompanied by introduction of Be, Ta and Eu in a rock which was originally very low in R.E.E. and other trace elements content. Marble is the only candidate for such a rock. If this second interpretation is correct, this lead us to consider W bearing calc-silicate gneiss as formed by metasomatic transformation of marble. Petrographic observations are not in favour of the second hypothesis especially in respect to the absence of apatite, sphene and sulfoarsenides in the marble. On the

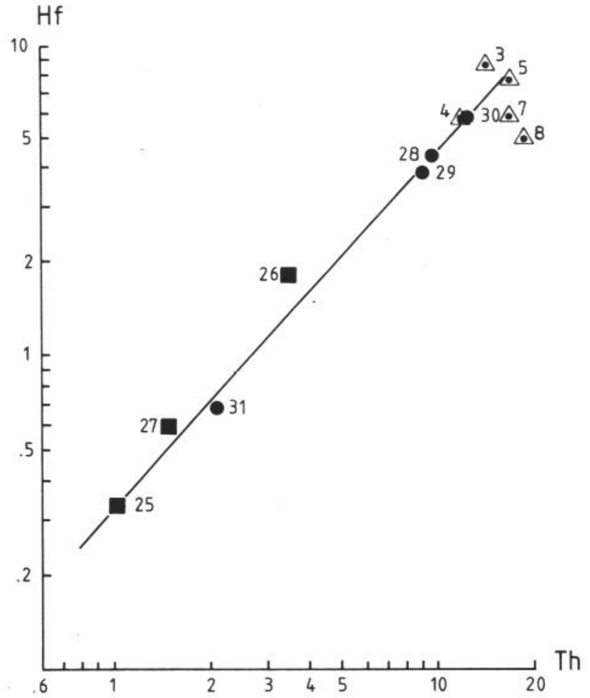

FIG. 11. — Bi-logarithmic plot (ppm) Hf-Th for the marble (squares) and calc-silicate gneiss (circles) (Table III) and for plagioclase gneiss (triangles) (Table I).

Diagramme bi-logarithmique (ppm) Hf-Th relatif aux marbres (carrés) et gneiss à silicates calciques (cercles) (Tableau III) et des gneiss plagioclasiques (triangles) (Tableau I).

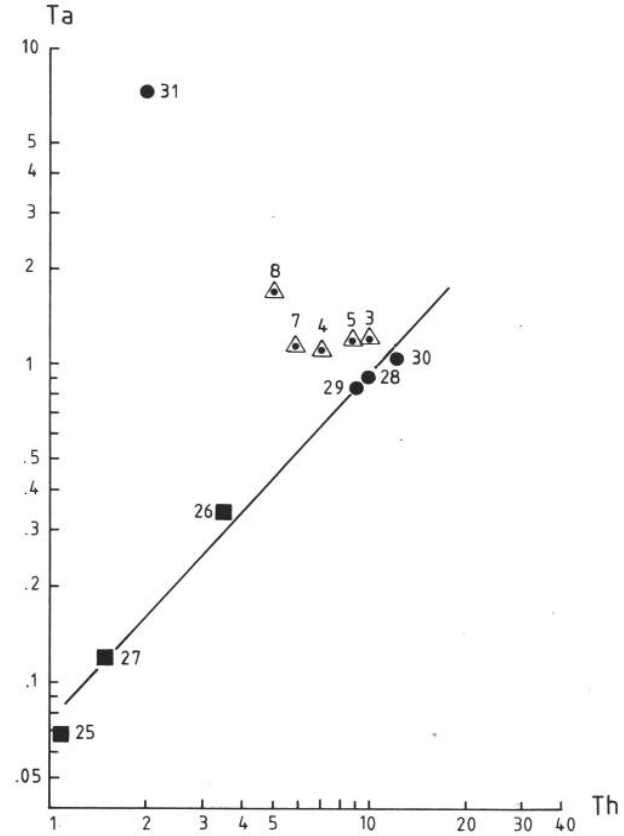

FIG. 12. — Bi-logarithmic plot (ppm) Ta-Th for the marble (squares) and calc-silicate gneiss (circles) (Table III) and for plagioclase gneiss (triangles) (Table I).

Diagramme bi-logarithmique (ppm) Ta-Th relatif aux marbres (carrés) et gneiss à silicates calciques (cercles) (Tableau III) et des gneiss plagioclasiques (triangles) (Tableau I).

other hand, the removal of RE elements except Eu requires a high solubility of complexes in the fluids. Known data on the stability of RE element complexes in fluids are not in favour of the first hypothesis (Sillen and Martell, 1964).

9. CONCLUDING REMARKS

Generally speaking, the presence of scheelite occurrences is related to the existence of bundles of marble and calc-silicate gneiss. Scheelite is not linked to any particular sedimentary cycle because it is dispersed into rocks of greatly different ages (at different levels in the cover and in the basement as well).

Structural and petrographic data suggest that deposition of scheelite occurred during a metamorphic episode predating folding phase P2. Mineralogical data show that in the mineralized areas there is an increase of Na in plagioclase and Mg in pyroxene in the scheelite bearing calc-silicate gneiss and a loss of Fe in biotite from the surrounding gneiss.

These results suggest that the tungsten-bearing fluids have induced chemical changes, *i.e.* metasomatism, in the calc-silicate gneiss lenses and their surroundings and possibly also in the marble lenses. The metasomatic fluids were able to carry tungsten and other elements over very long distance and scheelite deposition depended on the casual encounter of more calcic rocks during their travel.

The study of trace elements indicates that there is a geochemical linkage between W, Be, Ta and Eu. Calc-silicate gneiss in the mineralized area show an enrichment in these elements. W and Be are also at a higher level in the biotite gneiss around the mineralized lenses and this information can be used in geochemical prospection. It should be noted that these elements are those typically found in perigranitic W mineralizations, especially in the case of skarns. Le

Guyader (1983) has demonstrated that trace elements such as Ta and especially Eu, in contrast to the other R.E.E., are enriched in the inner zones (grenatites) of skarns, precisely where scheelite mineralizations occur. Ag, Hg, Sb, Mn are never higher than the regional geochemical background. These rules out a volcano-sedimentary origin of the Mittersill type (Maucher, 1976).

These results allow the authors to propose a perianatectic model which is defined as follows : above the anatexis isograd which is more or less parallel to the basement-cover boundary, there is an abundance of pegmatite-aplite mixed veins and small granitoïd bodies. These intrusives of limited importance are not related to nearby granitic masses (as there are no such rocks in the Tanneron Massif). Rather, they seem to be the remote expression of a deep-seated igneous intrusion process. The assumed granitic melt is probably able to rise up as small bodies below the anatexis isograd because of the thermic equilibrium with the surroundings. The bodies crystallize when they reach the anatexis isograd which acts as thermal trap. The high water content of this melt as inferred by the mixed pegmatic-aplite texture of the veins indicates a rather low temperature of intrusion. This is an argument in favour of a thermically controlled solidification at the anatexis isograd. Water expelled by the crystallization possibly contributed to the fluid responsible for the tungsten mineralizations.

Similarities between La Favière and other stratabound deposits can be found in the literature. Examples are : the San Luis province in Argentine (de Brodtkorb y Brodtkorb, 1979) where scheelite occurs together with fluorite and beryl ; the Borralha area in Portugal (Noronha, 1976) ; the NE province of Brazil (Salim *et al.*, 1980) where scheelite is found in association with molybdenite ; the Bindal area of Norway (Skaarup, 1974) where scheelite occurs with some Sn and Mo and where the W content seems to be related to the intensity of migmatisation ; the Colorado province in the U.S.A. (Tweto, 1960). In the Colorado province, there is a spatial correlation between mineralized calc-silicate gneiss and pegmatites and migmatites, a loss of iron in the mineralized bodies, an absence of fluorite and an antipathetic relation between calcite and scheelite.

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