YPMA (P.J.M.)
1963

25

THESE D'YPMA

Fascicule des croquis , tableux et cartes

La reprise des gites métalliques
de la province métallogénique de BELLEDONNE

1963

GRENOBLE

4è Partie

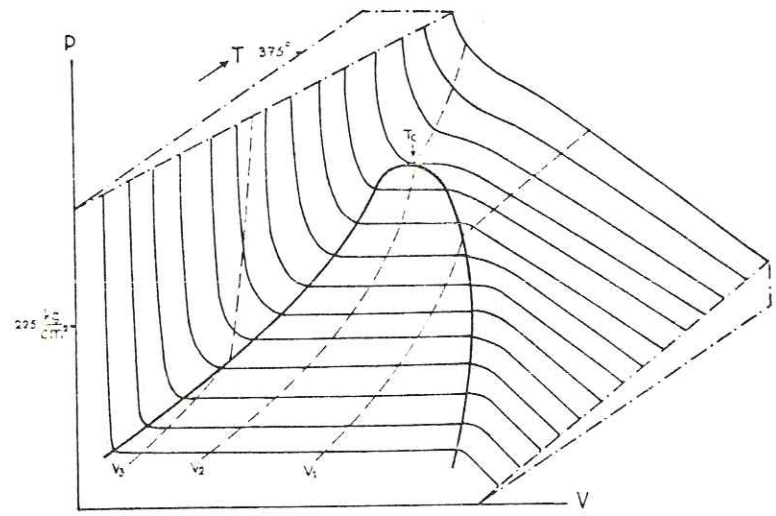


Fig. 1. Pressure-temperature-volume relations of water.

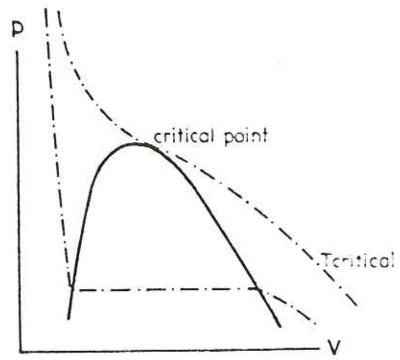


Fig. 2. Pressure-volume relations of a unary system.

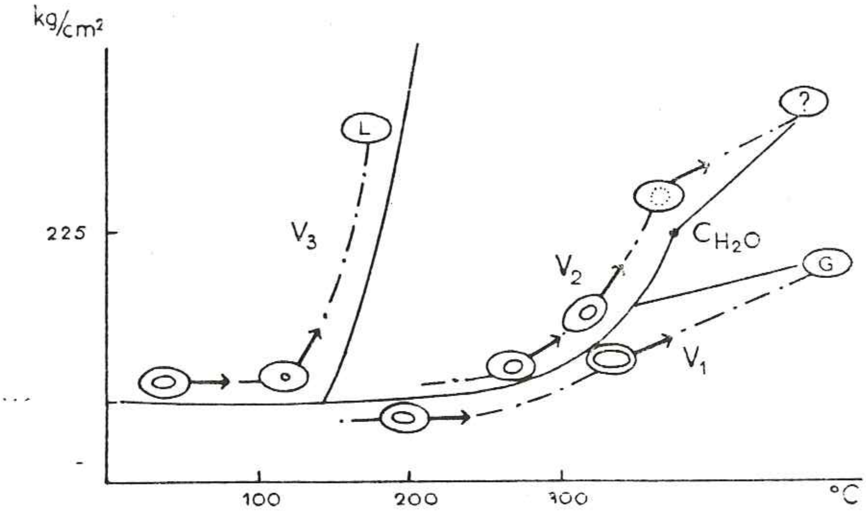


Fig. 3. Pressure increase on heating inclusions of different filling degrees, corresponding with V_1, V_2 and V_3 of figure 1.

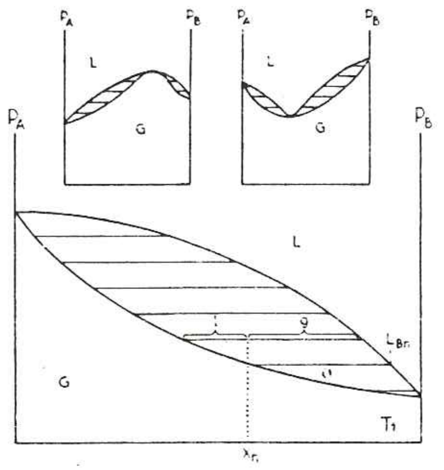


Fig. 4. Vapour pressure and vapour composition curves of a completely miscible binary system: the left inset indicates the course of the curves in case of maximum vapour pressure, the right one refers to the case of minimum vapour pressure.

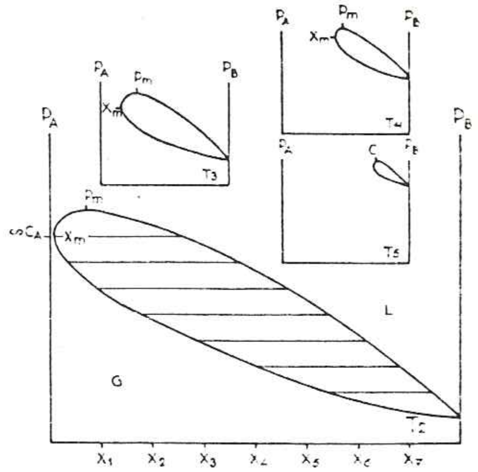


Fig. 5. Pressure-composition diagram of a binary system heated above the critical temperature of its most volatile component.

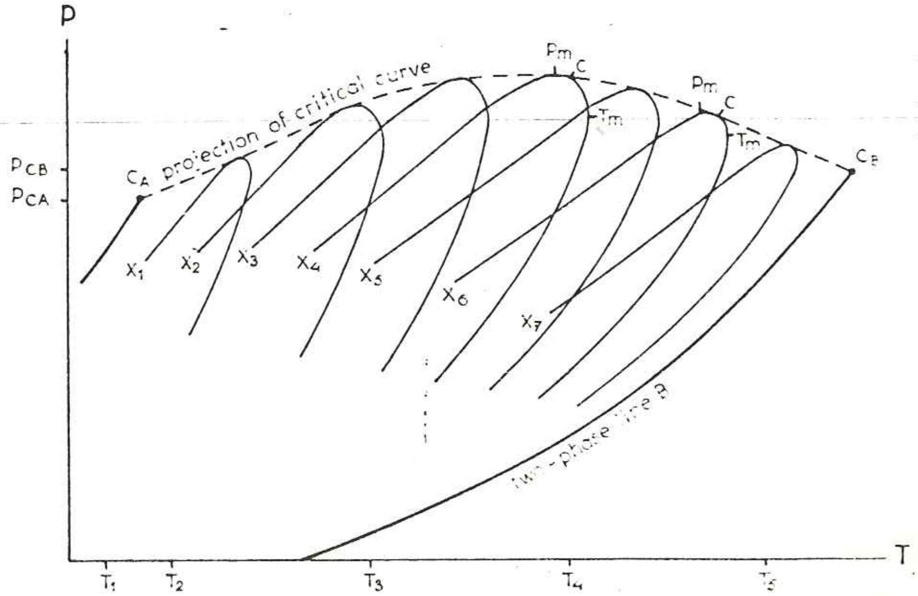


Fig. 6. Projection of the critical curve on the PT-plane, constructed as tangent line to PT-curves of different composition, corresponding to those of figure 5.

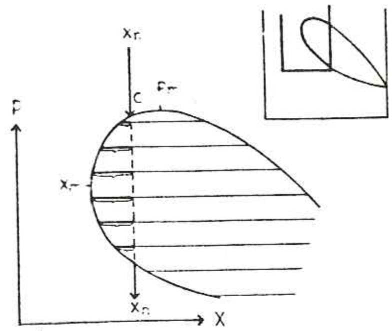


Fig. 7. Detail of a PX-diagram. Demonstrates critical phenomena, such as retrograde condensation.

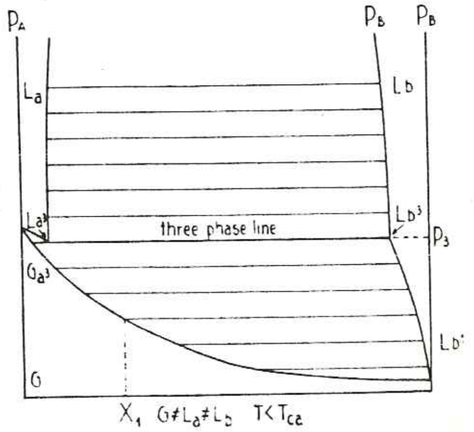


Fig. 8. PX-diagram of two partly miscible liquids at a temperature lower than the critical temperature (T_{ca}) of the most volatile component (P_A).

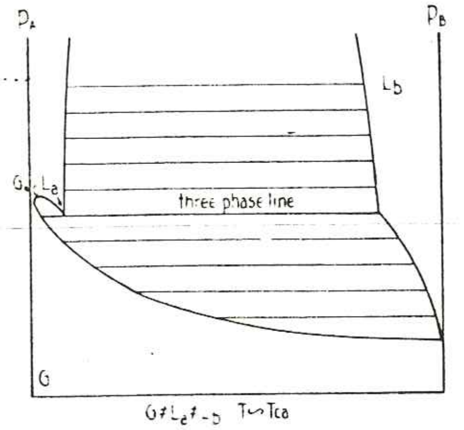


Fig. 9. PX-diagram of two partly miscible liquids at the critical temperature of component A.

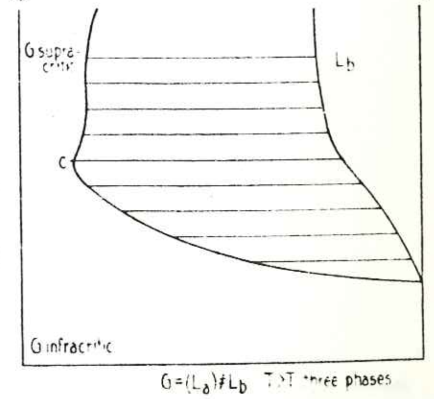


Fig. 10. PX-diagram of a partly miscible binary system at a temperature slightly higher than the three-phase temperature.

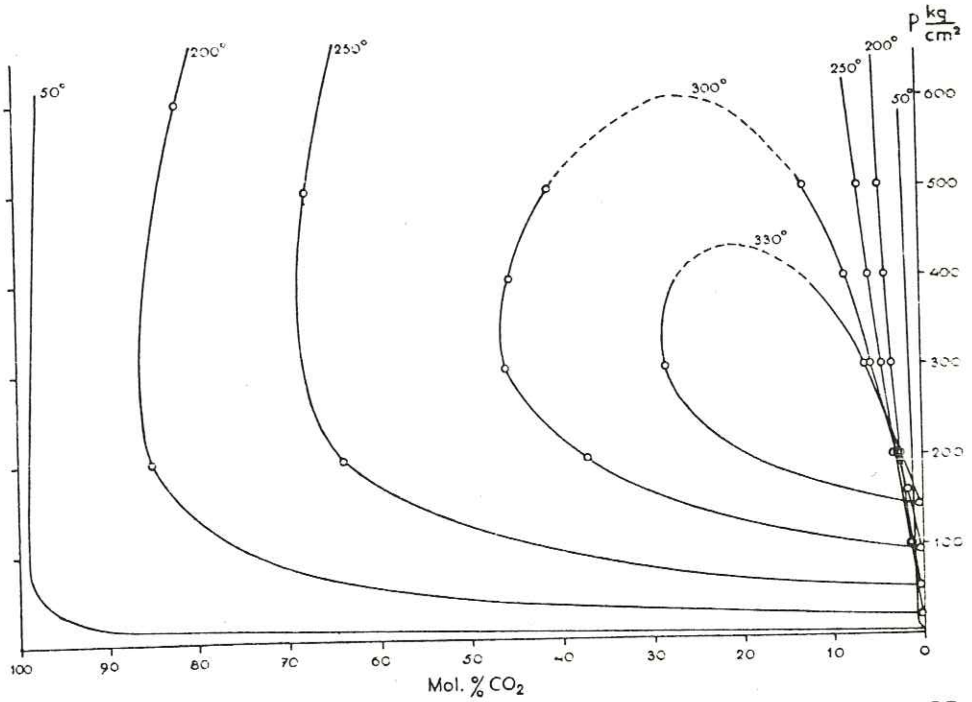


Fig. 11. The system H_2O-CO_2 at temperatures above the critical temperature of CO_2 according to data of Wiebe and Gaddy (1939) and Malinin (1959).

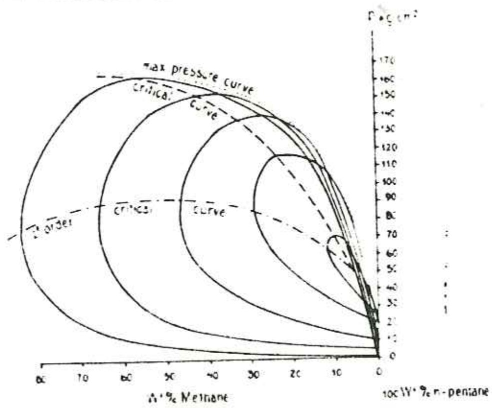


Fig. 12. Temperature and composition range in which retrograde condensation may occur with the system methane-n-penthane, according to Sage et al. (1942). The curves refer to the 38°, 71°, 104°, 138° and 171° C isotherms.

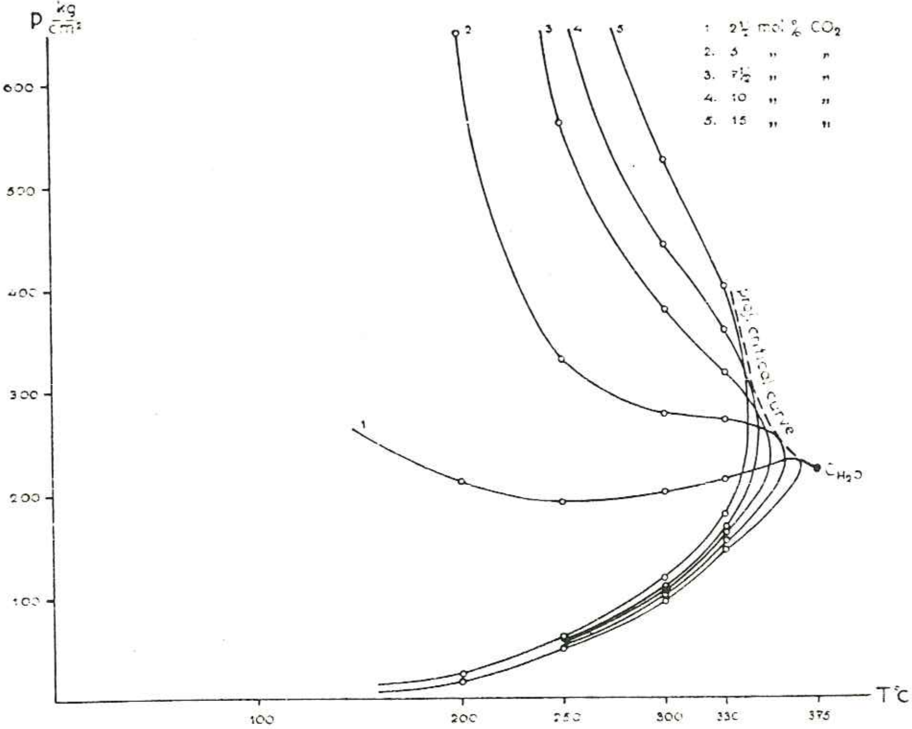


Fig. 13. Position of the critical curve of the system H_2O-CO_2 for solutions of 2.5 to 15 mol. % CO_2.

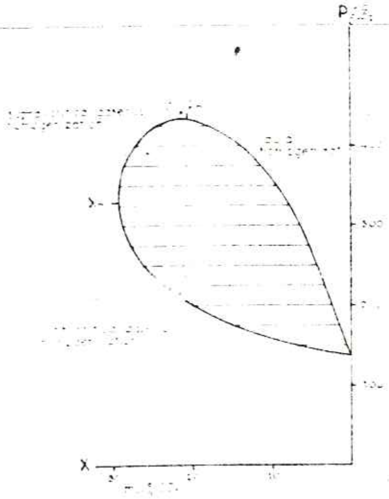


Fig. 14. The 330°-isotherm of the system CO_2-H_2O. The term supracritical gaseous homogenization refers to the phase transformation such as it is observed in the inclusions.

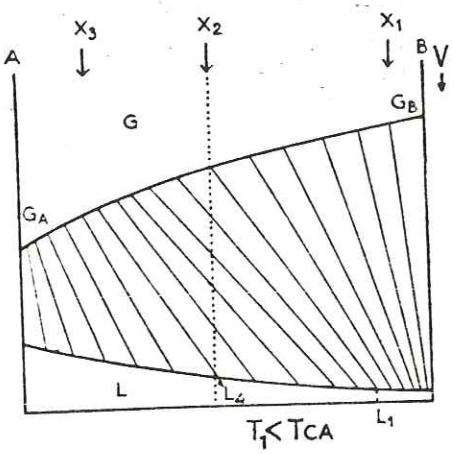


Fig. 15. VX-diagram of a completely miscible binary system at a temperature lower than the critical temperature of the most volatile component.

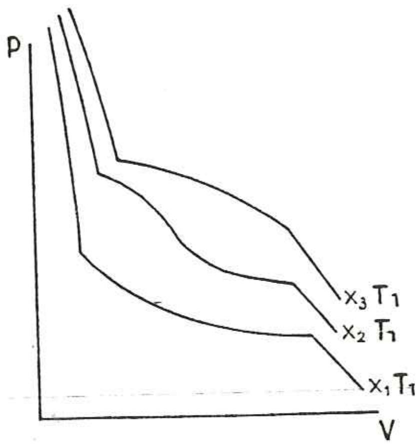


Fig. 16. Pressure increase on isothermal volume reduction of three different solutions corresponding with those of figure 15.

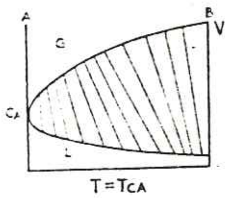


Fig. 17. VX-diagram of a completely miscible binary system at the critical temperature of the most volatile component.

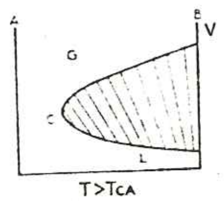


Fig. 18. VX-diagram of a completely miscible binary system above the critical temperature of the most volatile component.

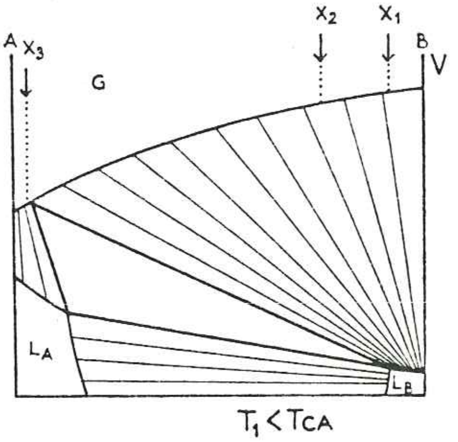


Fig. 19. VX-diagram of a partly miscible binary system below the critical temperature of the most volatile component (A).

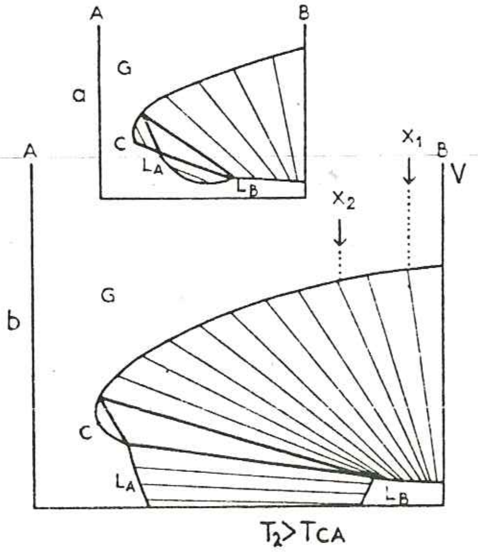


Fig. 20. VX-diagram of a partly miscible binary system above the critical temperature of the most volatile component, close to the temperature at which the composition of the A-rich liquid equals that of the gaseous phase. The inset-figure refers to the case that the composition of the A-rich liquid equals that of the B-rich liquid.

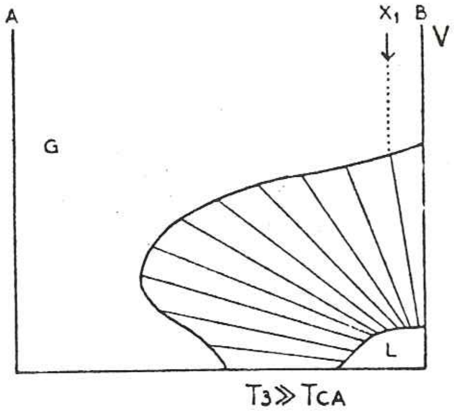
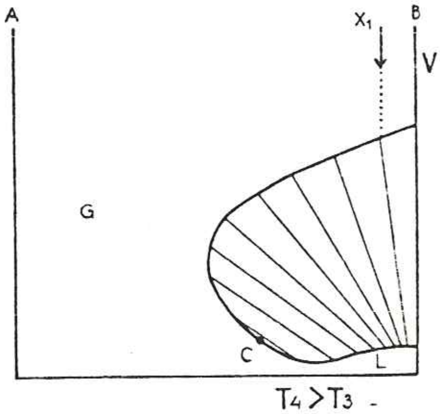


Fig. 21. VX-diagram of a partly miscible system at a temperature higher than the three-phase-temperature.

Fig. 22. VX-diagram of an originally partly miscible binary system at a temperature at which miscibility becomes complete.



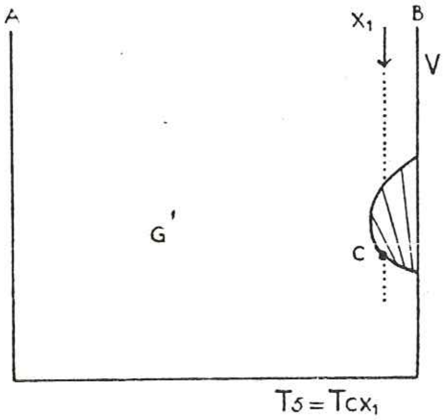
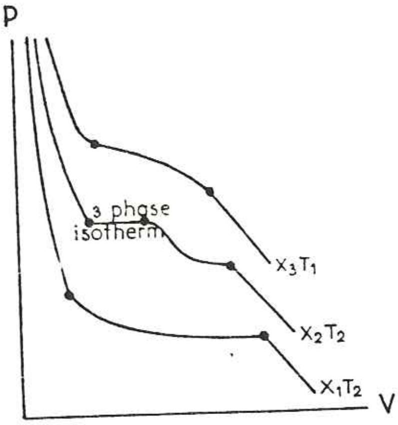


Fig. 23. VX-diagram of a binary system at the critical temperature of a solution of composition X_1.

Fig. 24. Rate of pressure increase on isothermal volume reduction of solutions and mixtures of compositions corresponding with those of figure 19.



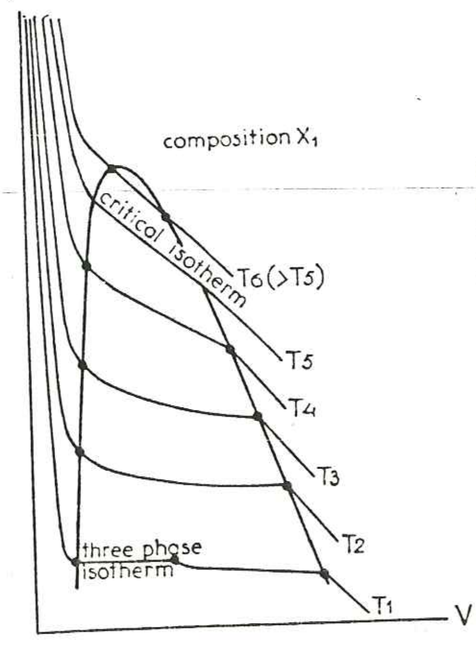


Fig. 25. Rate of pressure increase on isothermal volume reduction of a partly miscible binary system at temperatures corresponding with those of the figures 19, 20, 21, 22 and 23. The knick-points in the curves are indicated by dots.

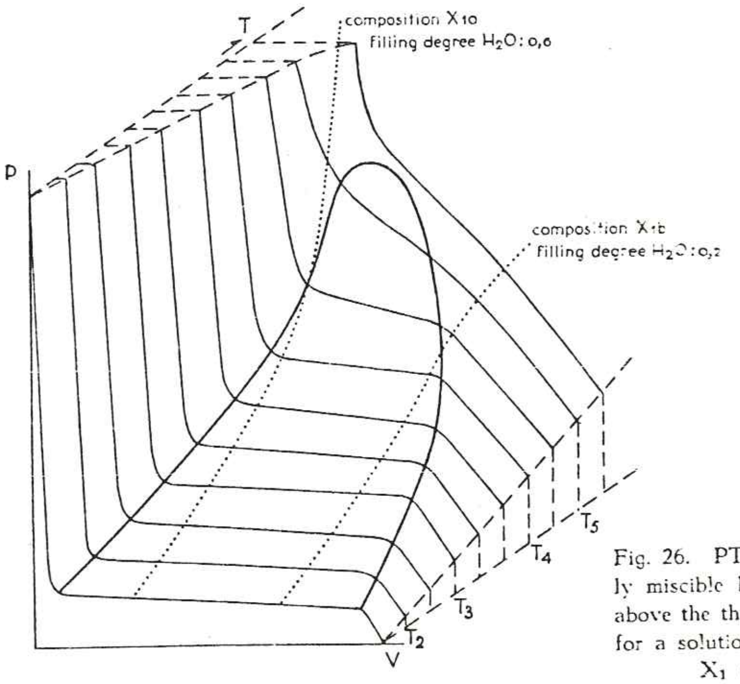


Fig. 26. PTV-diagram of a partly miscible binary system heated above the three-phase temperature for a solution corresponding with X_1 of figure 19.

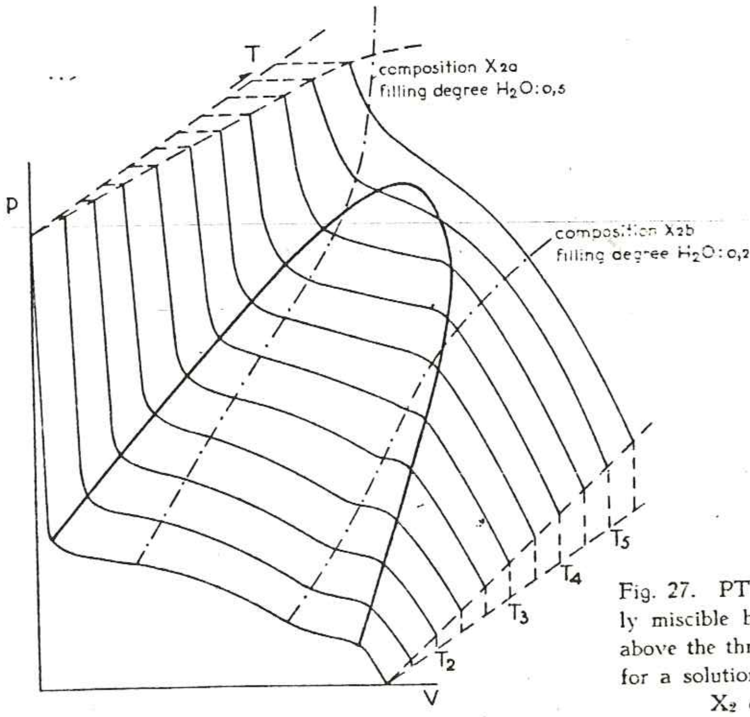


Fig. 27. PTV-diagram of a partly miscible binary system heated above the three-phase temperature for a solution corresponding with X_2 of figure 19.

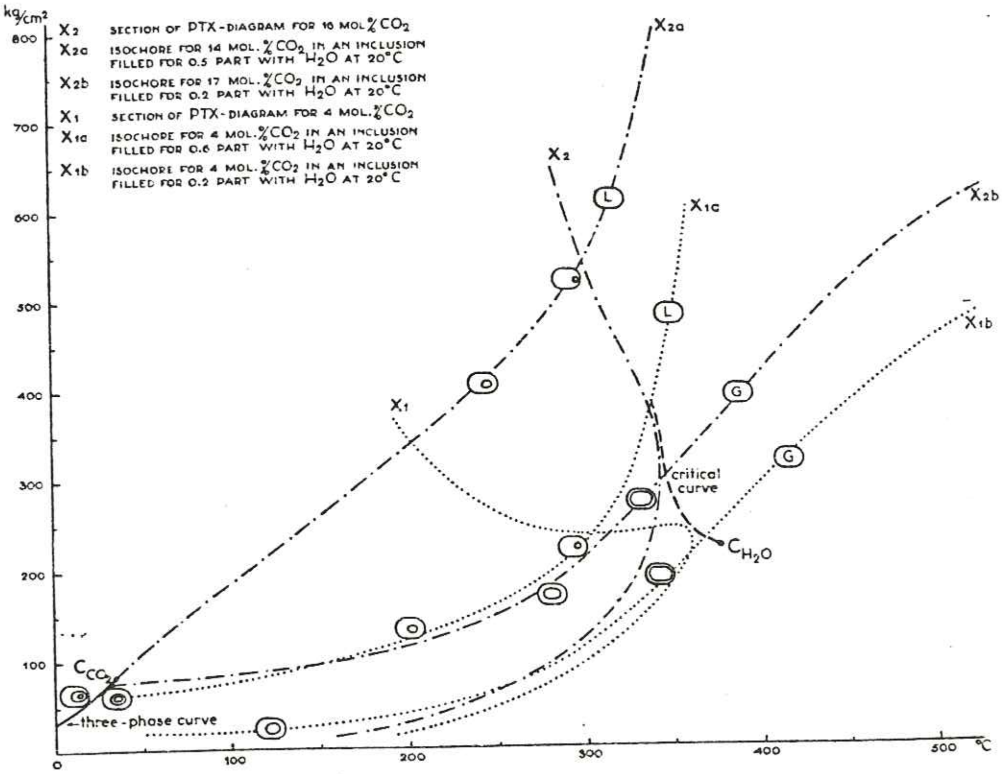


Fig. 28. Relation between inclusion-type and mode of homogenization as shown by the isochores. These correspond with two types of composition and filling degree.

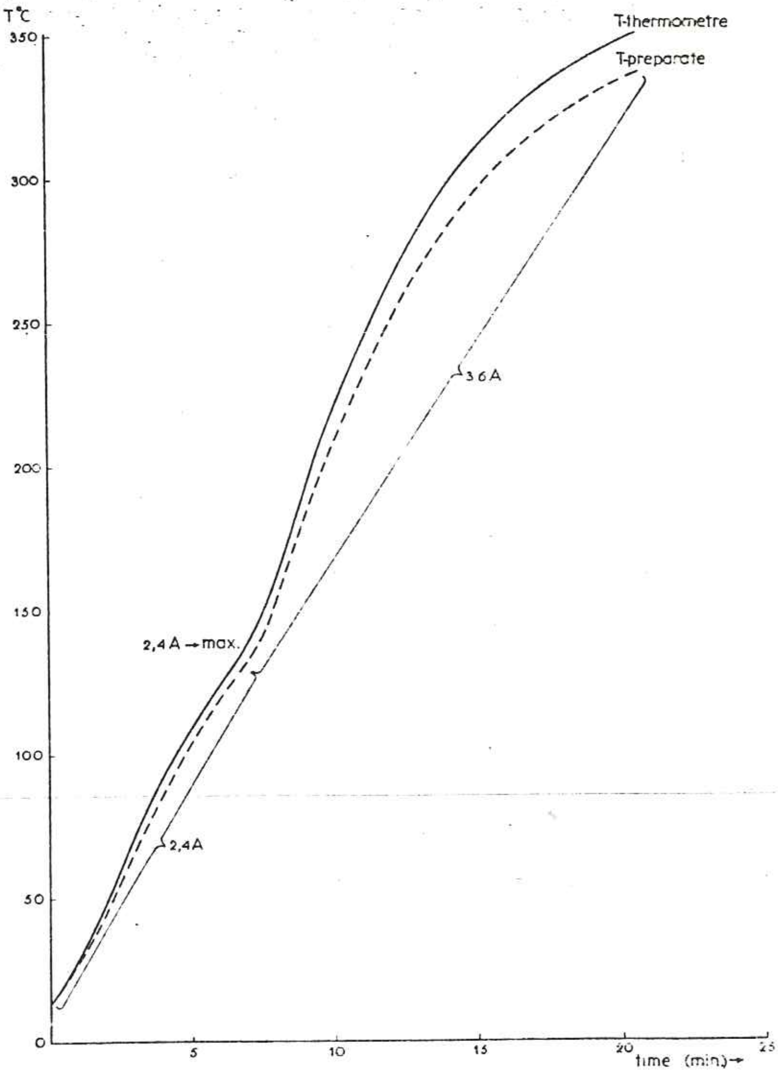


Fig. 29. Temperature differences between sample and thermometer with the Leitz-Weygand heating stage, expressed as function of time and temperature. The amperages refer to the strength of current used.

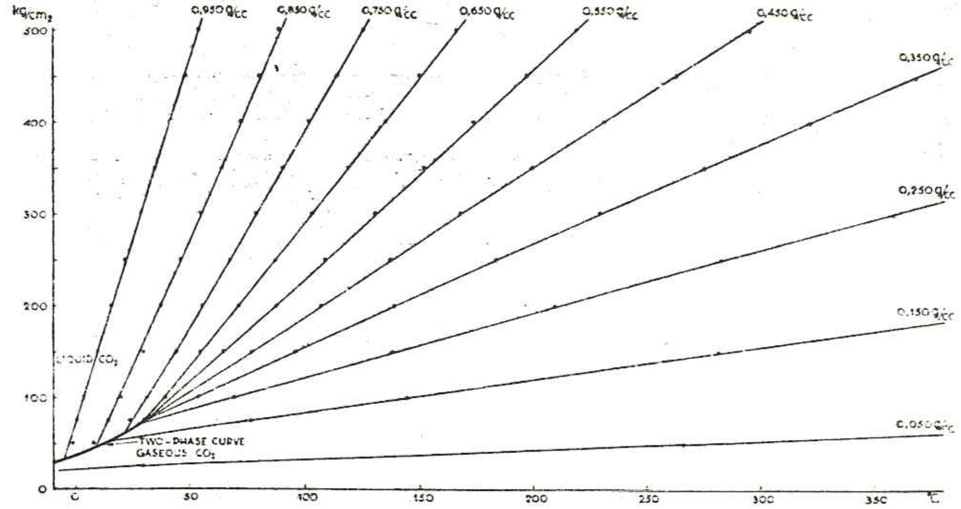


Fig. 30. Density of carbondioxide, according to Kennedy (1954).

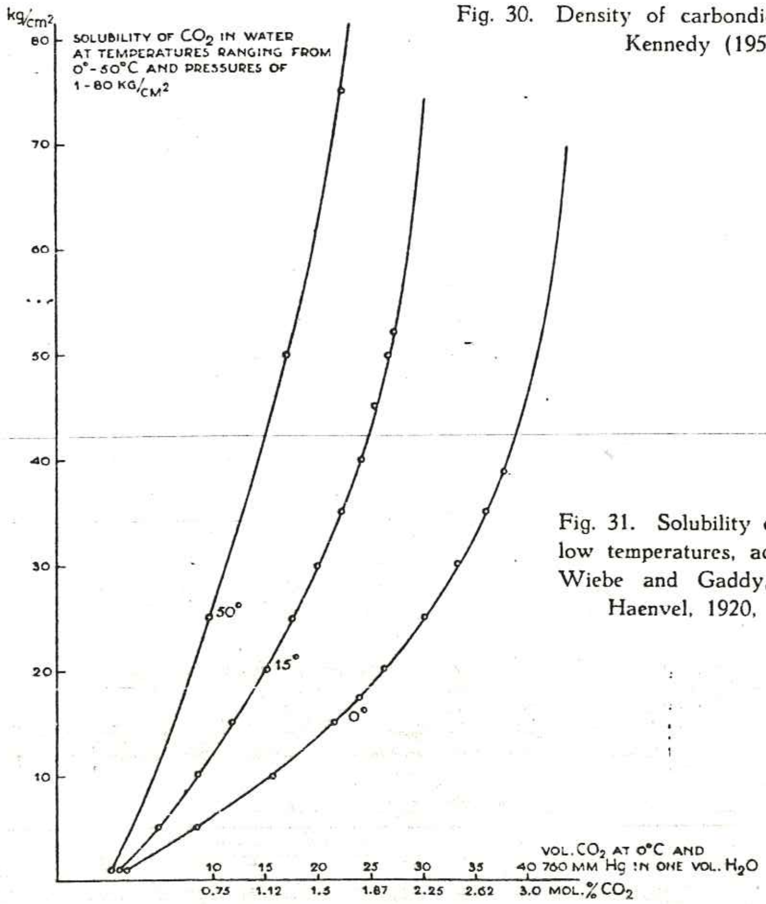


Fig. 31. Solubility of CO_2 in water at low temperatures, according to data of Wiebe and Gaddy, 1939 (50°) and Haenvel, 1920, (0° and 15°).

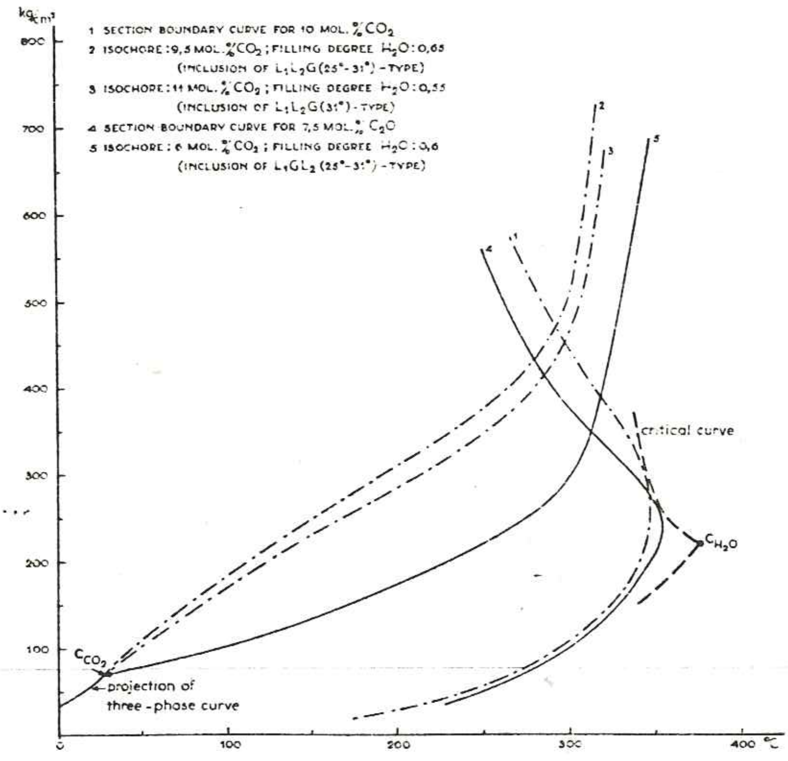


Fig. 32. Courses of the isochores for several CO_2-bearing inclusions, corresponding with those of the younger vein quartz.

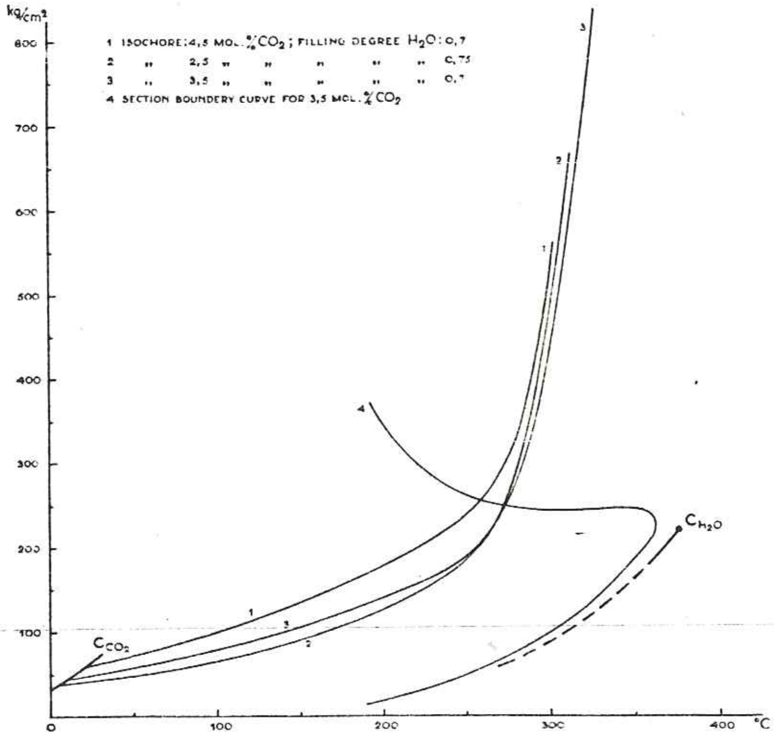


Fig. 33. Courses of the isochores for inclusions of low CO_2-content, corresponding with those of the older vein quartz.

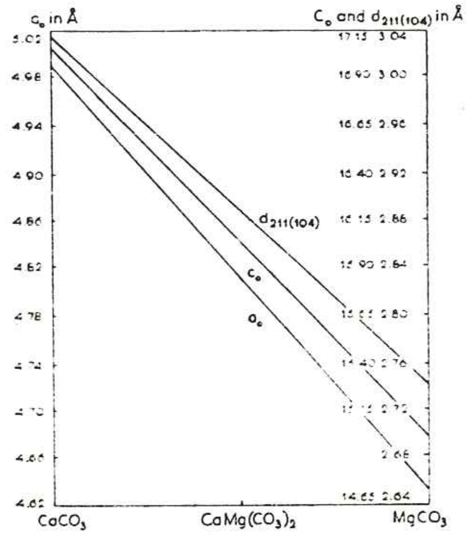


Fig. 34. Variation of unit cell dimensions, and the {211} lattice spacing of dolomite of a hypothetical calcite and magnesite solid solution series, according to Goldsmith and Graf (1958).

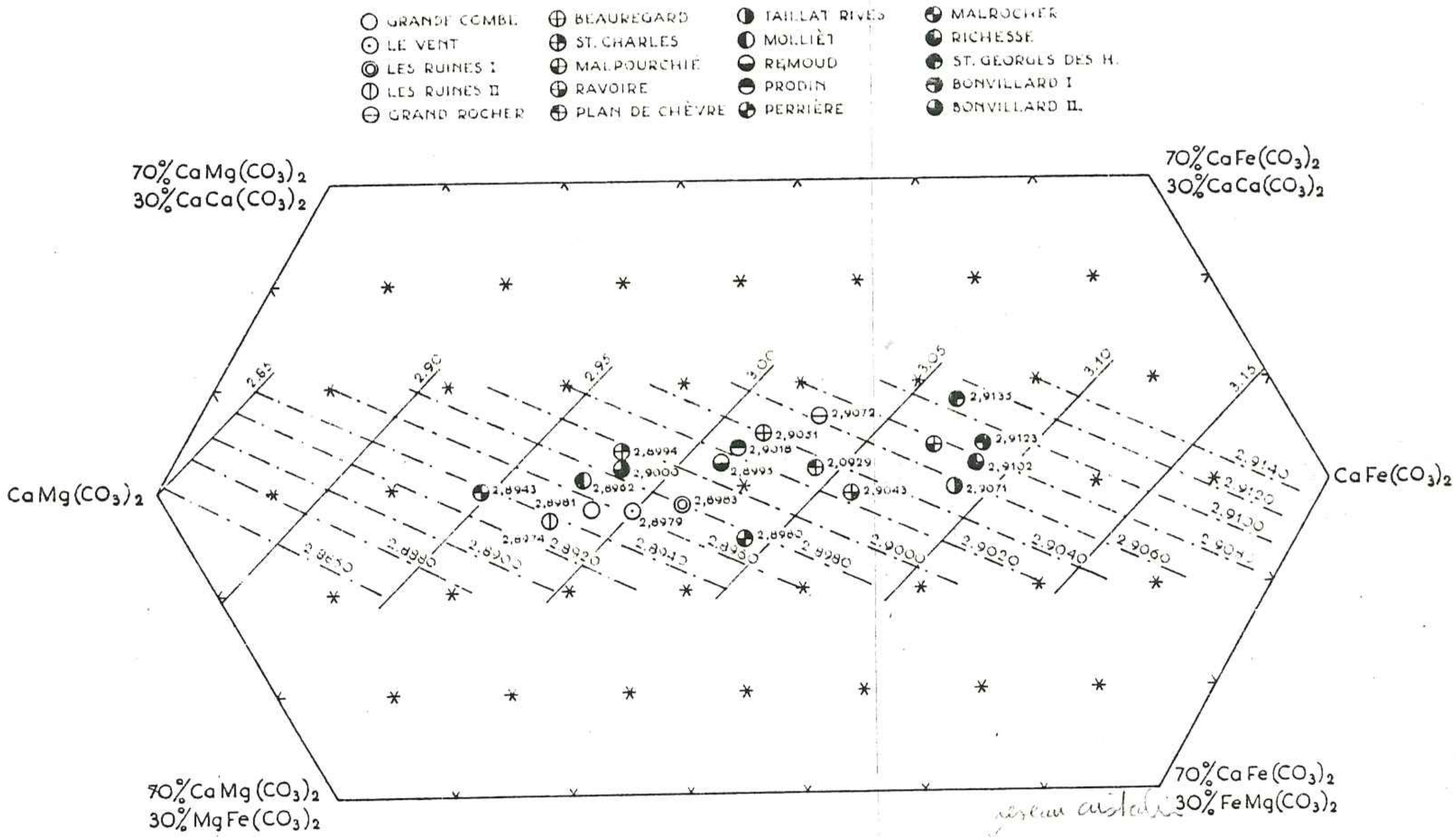


Fig. 35. Variation of specific gravity and {211} lattice spacings of dolomite and ankerite.

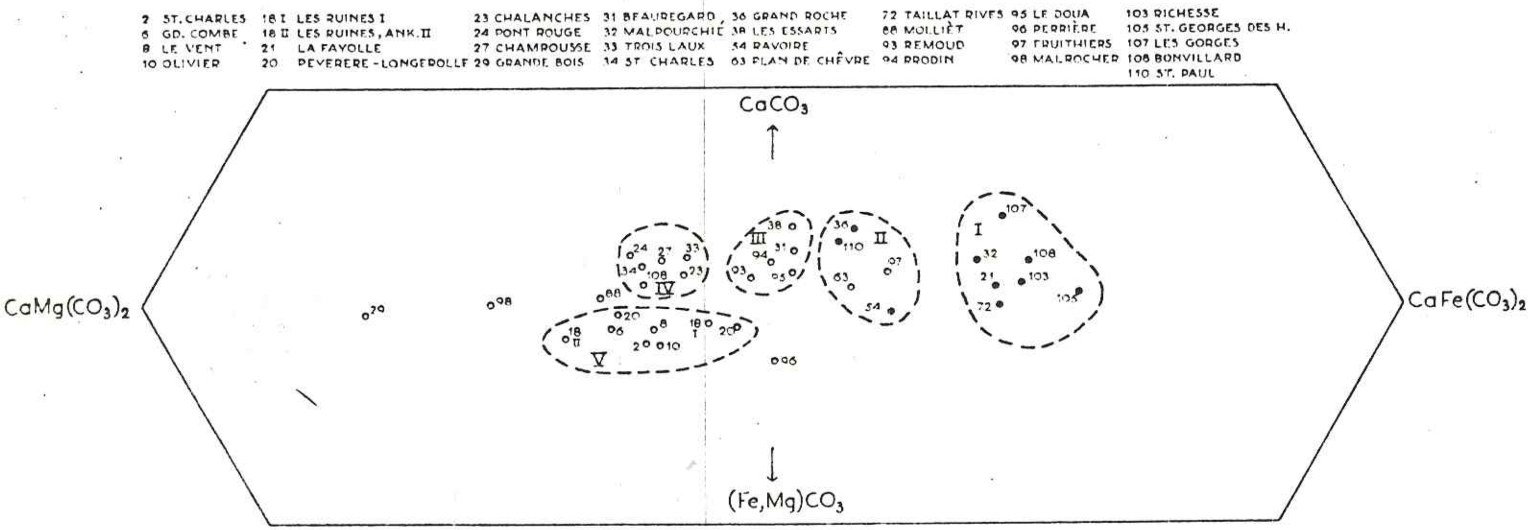


Fig. 36. Variation of chemical composition of ankerite, representing the 5 genetical groups.

Fig. 37. Siderite and ankerite (ank.) replaced by calcite, Malpourchié.

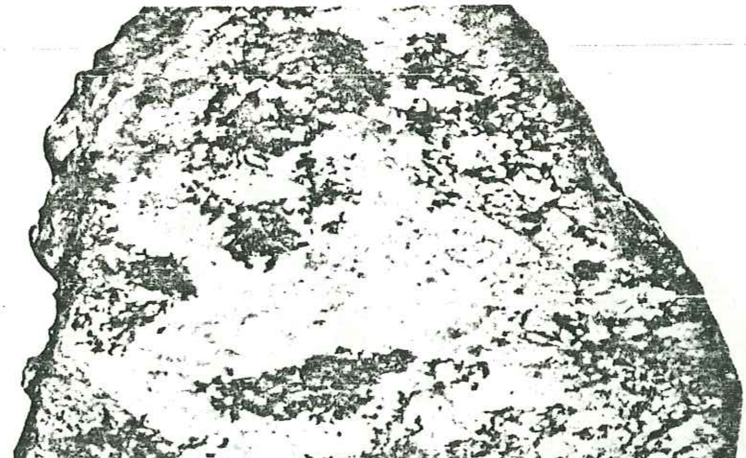


Fig. 38. Age relations between siderite and ankerite appears from replacement of siderite (dark gray) by ankerite (light gray). Note the arbitrarily shaped replacement relics. Les Gorges, 1 x.

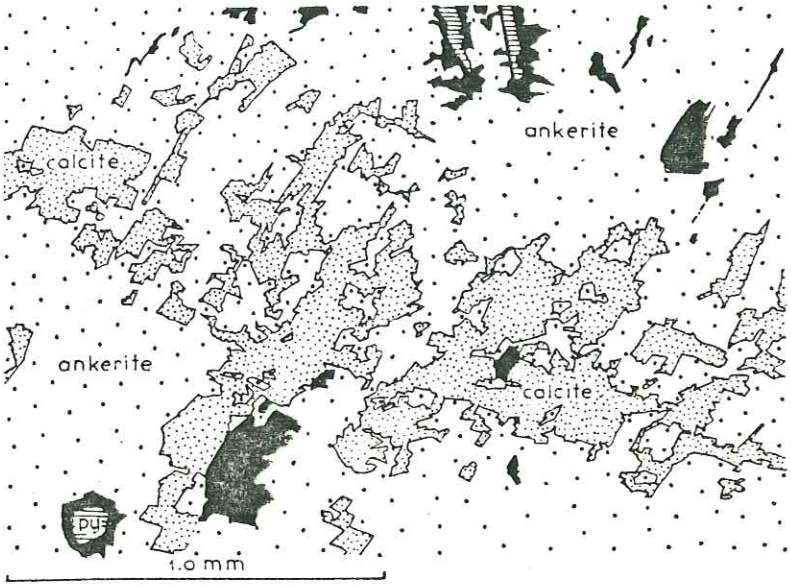


Fig. 39. Replacement of ankerite by calcite starts in the centres of the ankerite crytals, thus pretending the calcite being a replacement relic. Calcite is crystallographically oriented upon ankerite. St. Charles, Allemont.

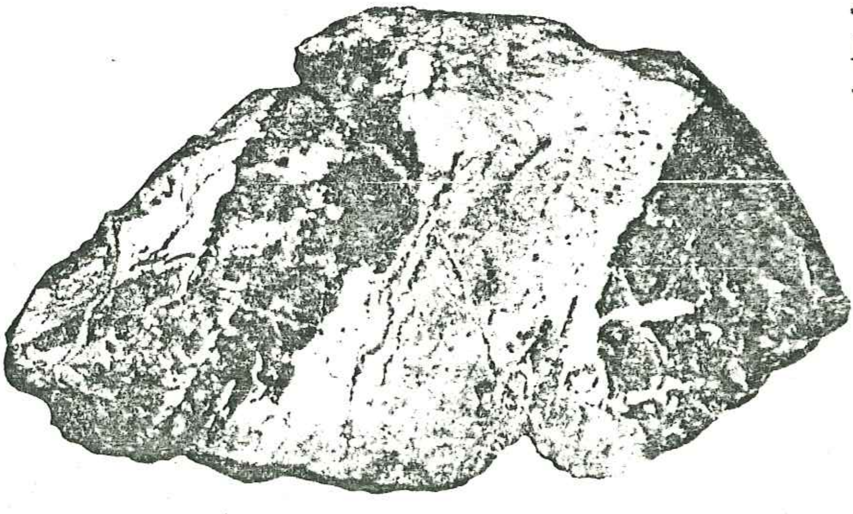


Fig. 40. Veins and veinlets of ankerite dissect siderite (dark gray). Les Fruithiers. 1 x.

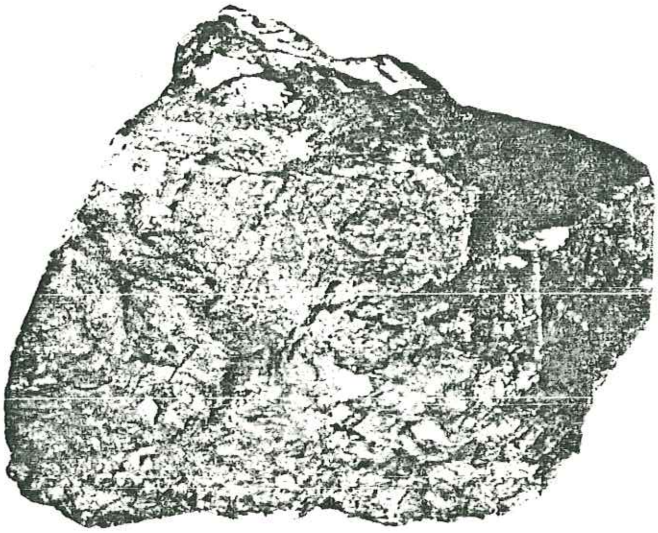


Fig. 41. Large rhombohedral crystals of ankerite. Found in vugs of the Grande Combe vein. ²/₃ x.

	2 ST. CHARLES ankerite	6 GRANDE COMBE ankerite	8 LE VENT ankerite	10 [illegible] ankerite	18 LES RUINES ankerite II	18 LES RUINES ankerite I	20 PEYERERE ankerite
FeO	14.51	13.57	14.75	13.99	8.56	11.98	15.32
MnO	0.48	0.24	0.35	0.38	0.40	0.44	0.19
MgO	12.29	13.04	12.47	11.50	9.72	8.56	9.70
CaO	26.78	27.78	27.85	26.00	19.24	21.00	24.54
Fe_2O_3	0.73	0.96	0.64	0.76	1.26	0.15	0.25
CO_2	42.16	40.66	43.10	39.92	30.10	32.56	37.50
H_2O	1.76	0.76	3.61	1.77	0.58	0.94	1.00
res.	0.72	2.48	0.73	5.48	30.48	24.70	11.92
	99.43	99.49	100.70	99.80	100.34	100.33	100.42

	20 PEYERERE ankerite	20 LONGEROLLE ankerite	21 LA FAYOLLE ankerite [illegible]% siderite	23 CHALANCHES ankerite 10% calcite	24 PONT ROUGE ankerite [illegible]% calcite	27 CHAMROUSSE 50% ankerite 6% calcite	31 BEAUREGARD 91% ankerite [illegible]% calcite
FeO	14.04	8.28	23.84	12.20	8.44	6.77	13.83
MnO	0.12	0.14	1.48	1.84	2.07	0.77	2.32
MgO	9.56	7.91	7.40	10.50	9.48	6.25	8.40
CaO	23.64	17.20	21.70	30.20	31.50	18.58	27.90
Fe_2O_3	-.-	0.14	2.76	1.64	5.14	1.56	2.35
CO_2	36.18	26.64	40.62	39.20	39.10	25.52	38.30
H_2O	0.97	1.09	0.79	1.57	1.62	0.92	1.19
res.	14.44	37.84	1.02	2.18	2.26	40.00	4.78
	99.96	99.24	99.61	99.33	99.61	100.37	99.07

	32 MALPOURCHIÉ ankerite	33 TROIS LAUX 85% ankerite 15% calcite	34 ST. CHARLES 96% ankerite 4% calcite	36 GRANDE ROCHE 86% ankerite 7% calcite	38 LES ESSARTS 95% ankerite 5% calcite	54 RAVOIRE ankerite	63 PL. DE CHÈVRES ankerite
FeO	17.68	12.80	12.20	12.82	12.73	16.26	18.24
MnO	3.09	2.04	1.29	3.44	2.45	0.89	0.52
MgO	8.40	4.25	11.62	6.88	7.92	6.62	8.14
CaO	26.40	25.50	29.60	28.44	29.52	22.30	26.78
Fe_2O_3	5.98	3.26	1.36	2.92	2.52	1.52	0.92
CO_2	36.88	31.20	42.21	37.84	41.04	35.34	40.82
H_2O	3.16	1.57	0.87	0.68	2.28	1.16	1.33
res.	1.36	18.82	0.06	6.54	0.74	16.44	2.52
	100.31	99.46	99.21	99.56	99.20	100.53	99.77

	72 TAILLAT RIVES ankerite	81 GIRODET ankerite 5% calcite	83 VAUJALAZ ankerite	92 ST. HUGON ankerite	93 REMOUD 95% ankerite 5% calcite	94 PRODIN ankerite	95 LE DOUA ankerite
FeO	21.00	3.51	12.24	23.64	15.20	11.54	14.24
MnO	1.77	0.22	0.22	1.44	0.58	0.58	0.46
MgO	5.98	4.72	6.58	9.54	9.79	6.87	8.70
CaO	26.04	11.16	15.74	19.46	28.20	20.56	25.02
Fe_2O_3	2.23	4.66	1.34	3.00	2.16	2.75	2.22
CO_2	38.70	15.86	27.04	39.80	40.46	29.02	37.38
H_2O	1.09	1.01	2.00	1.94	1.11	1.33	1.58
res.	2.34	58.60	34.20	0.98	1.74	26.50	9.59
	99.15	99.74	99.36	99.80	99.24	99.15	98.99

	96 PERRIÈRE ankerite 1% calcite	97 LES FRUITHIERS ankerite	98 MALROCHER ankerite	103 RICHESSE ankerite	105 ST. GEORGES D. H. ankerite	105 ST. GEORGES D. H. ankerite and goethite	107 LES GORGES ankerite
FeO	14.34	15.52	8.62	16.12	17.40	15.36	14.84
MnO	0.73	2.12	0.46	2.00	5.40	5.16	2.21
MgO	8.35	6.84	13.74	4.28	4.39	3.87	4.15
CaO	21.36	25.10	26.20	20.96	24.84	24.40	23.18
Fe_2O_3	0.84	2.40	1.04	3.04	9.21	11.78	0.20
CO_2	33.88	34.80	39.76	32.38	36.08	32.80	31.42
H_2O	1.46	1.62	1.48	0.27	1.80	2.90	0.31
res.	18.24	12.56	7.98	21.50	1.14	3.88	23.30
	99.20	100.96	99.28	100.55	100.26	100.10	99.61

	107 LES GORGES ankerite 10% siderite	108 BONVILLARD ankerite I	108 BONVILLARD ankerite II	110 ST. PAUL ankerite	110 ST. PAUL 93% ankerite 7% calcite	68 MOLLET ankerite	
FeO	22.84	20.20	13.20	16.26	16.39	11.74	
MnO	2.75	2.94	0.18	0.79	0.93	0.41	
MgO	4.67	5.18	10.87	6.93	7.73	12.00	
CaO	26.44	27.40	25.94	26.16	28.98	26.68	
Fe_2O_3	2.40	2.27	1.92	2.86	3.16	2.09	
CO_2	37.70	38.30	36.17	34.28	38.14	38.18	
H_2O	1.64	0.99	1.76	1.30	1.50	2.10	
res.	1.30	2.40	10.30	11.12	2.72	6.48	
	99.74	99.68	100.34	99.80	99.55	99.70	

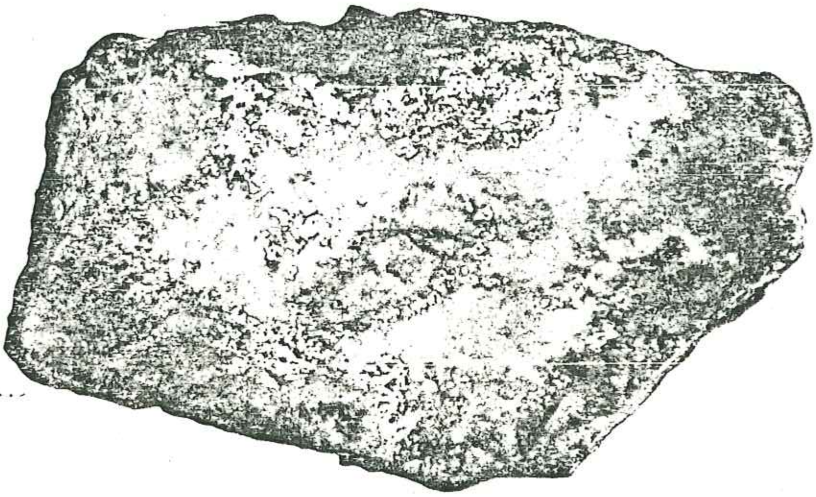


Fig. 42. Arsenopyrite (white) mainly located at the outside of the vein and around an ankerite fragment (dark gray) embedded in calcite I (light gray). Chalanches. 1 x.

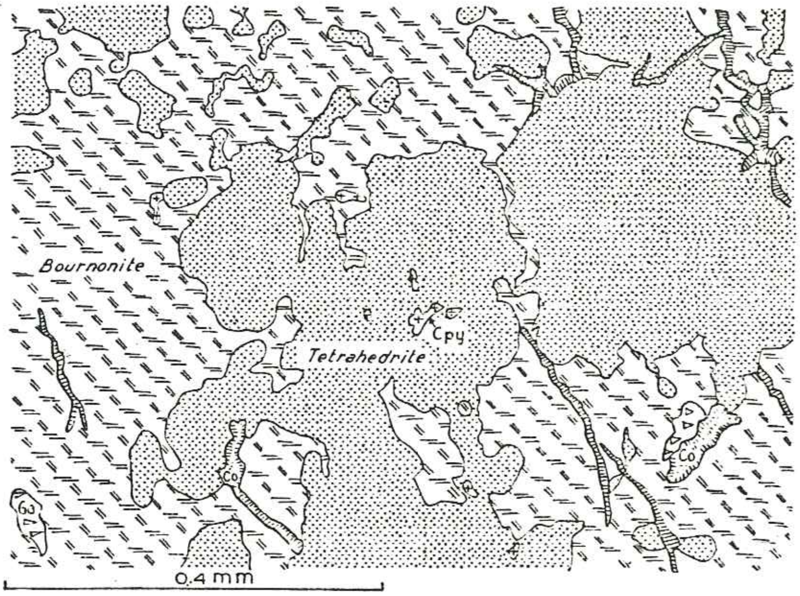


Fig. 43. Chalcopyrite (Cpy) and tetrahedrite replaced by bournonite and galena (Ga); veinlets of secondary covellite (Co). Galena is confined to bournonite, chalcopyrite or tetrahedrite. Les Ruines.

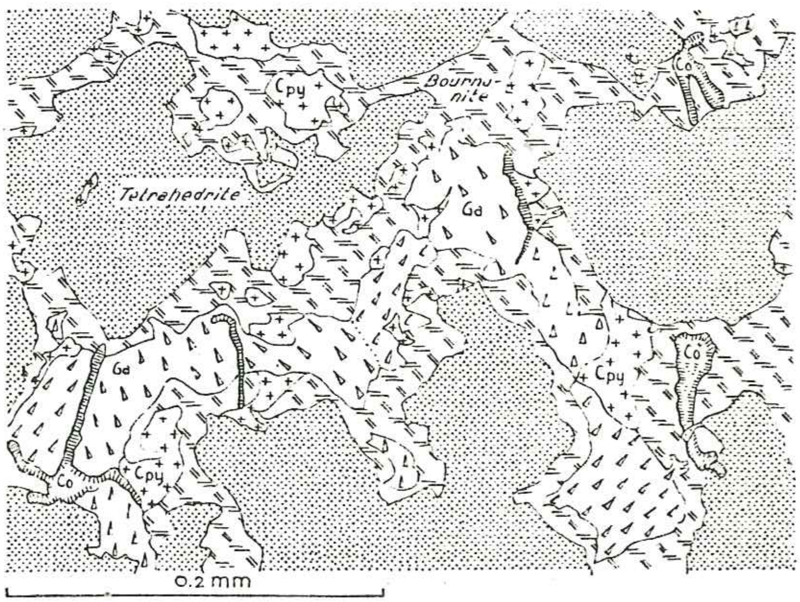


Fig. 44. Bournonite as reaction product between galena and tetrahedrite. Clusters of small chalcopyrite crystals at the borders of tetrahedrite. Remoud.

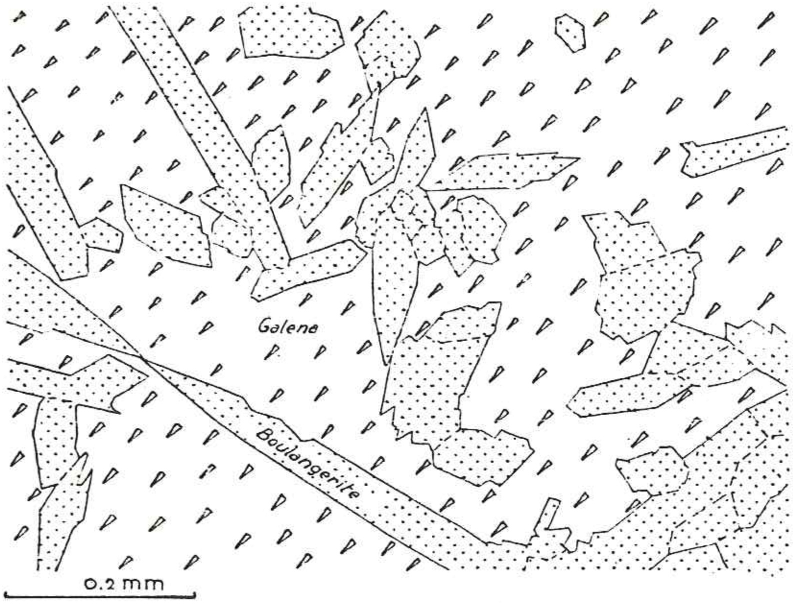


Fig. 45. Needles of boulangerite in galena. Peyrère-Longerolle.

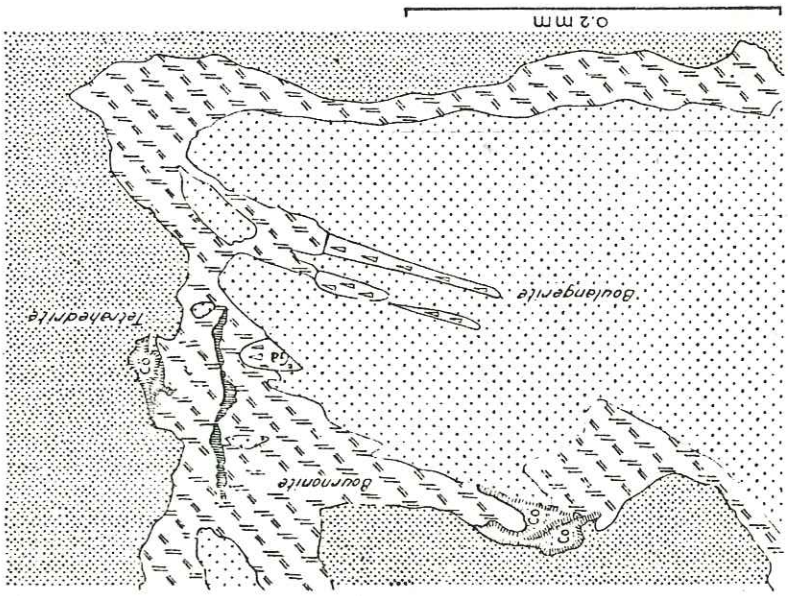


Fig. 46. Boulangerite and bournonite as reaction products of tetrahedrite and younger galena (Ga). Chalanches.

{hkl}	Boulangerite of Longerolle	Boulangerite of Pribram (Czech)	Boulangerite of Wolfsberg (Germ.) according to Hiller, (1938)
{004}	3.71	3.70 st.	3.70 st.
		3.21	3.21
{600}	3.00	3.00	3.00
{205}	2.80 st.	2.80 v.st.	2.80 v.st.
{305} {114}	2.69	2.69	2.69
	2.59		2.59
{414} {604}	2.31	2.33	2.34
{800}		2.23	2.23
		2.14	2.14
	2.00	2.01	2.02
{804} {407}	1.92	1.92	1.92
{008}	1.86	1.86 st.	1.86 st.
{904}		1.76 broadened	1.76
	1.47	1.47	1.47

Because of the absence of the 3.21, 2.23 and 2.14 d-values the presence of falkmanite in the Longerolle deposit cannot be excluded, although it is very unlikely, since Haudour's X-ray powder diagram from a lead-sulpho-salt of Peychagnard undoubtly points to boulangerite.

Boulangerite has been taken for antimonite in the occurrences of Laffrey (Lacroix, 1893), and probably also in Chalanches (Hericart de Thury, 1806) and Esserts-Blay (Hollande, 1911), since in the latter deposits the author only boulangerite has met.

As was mentioned for bournonite, boulangerite occurs in a typical paragenetical position being a reaction product of tetrahedrite-bournonite with galena. The figure (46) gives the mutual relations.

Boulangerite of the Longerolle deposit has been replaced selectively by cerussite, whereas its host (galena) has hardly been attacked (fig. 45, of an unaltered specimen).

21 Calcite

According to their mode of occurrence three types of calcite can be discerned:

<u>a</u> Calcite in barren veins from the basic rocks of the Inner Zone.

In this vein type calcite is accompanied by asbestos epidote, chlorite and other minerals that have been produced by the retrograde metamorphism of ultrabasic or amphibolitic rocks. Alteration of plagioclase yielded calcite, alteration of hornblendes or pyroxenes yielded epidote and chlorite. This vein type is mainly located on faults in the Inner Zone, the same ones on which the ore veins are situated and therefore it may have been intermingled with type b 1, from which it can be distinguished by its substantially higher Fe/Mn ratio (analyses are tabled).

	23 CHALANCHES calcite I CO₂ calculated	23 CHALANCHES calcite II CO₂ calculated	27 CHAMROUSSE 80% calcite 5% Fe-hydroxides	29 GRANDE BOIS calcite	29 GRANDE BOIS 80% calcite 7% dolomite	30 ROCHE NOIR 90% calcite 5% ankerite	32 MALPOURCHIÉ 80% calcite 5% sid., 5% ank.
FeO	4.75	trace	-.-	-.-	-.-	2.59	6.35
MnO	2.06	0.32	1.15	1.81	2.63	5.40	3.96
MgO	0.25	trace	1.46	2.04	2.40	1.04	1.31
CaO	49.58	55.72	26.96	52.60	34.50	40.74	34.40
Fe_2O_3	-.-	-.-	12.20	1.43	10.50	7.38	5.64
CO_2	42.36	43.96	21.30	41.34	28.00	36.12	34.76
H_2O	-.-	-.-	3.10	0.54	2.50	0.98	2.56
res.	-.-	-.-	33.84	0.64	19.14	4.94	9.64
	100.00	100.00	100.01	100.40	99.67	99.19	98.62

	33 TROIS LAUX 98% calcite 2% siderite	EPIDOTE-CALCITE VEIN NEAR R.D.L COCHE 50% calc., 5% dolom 5% Fe-hydroxides	20 PEYERERE 25% calcite 25% dolomite	BOUT DU MONDE 85% calcite 10% Fe-hydroxides	CHAPELLE DU B. calcite	24 PONT ROUGE 85% dolomite 10% calcite	29 GRANDE BOIS 50% dolomite 25% calcite
FeO	1.64	-.-	0.67	1.09	-.-	0.72	1.47
MnO	1.34	1.02	0.17	0.14	0.12	1.32	1.63
MgO	0.34	0.88	0.53	-.-	0.83	16.66	8.41
CaO	53.62	25.70	33.20	43.60	52.28	31.02	27.06
Fe_2O_3	1.18	12.29	12.60	9.98	4.71	1.84	5.82
CO_2	40.80	19.20	30.74	35.24	39.80	42.34	30.08
H_2O	0.73	3.32	4.70	3.38	0.62	1.30	1.57
res.	0.18	36.70	12.68	5.62	1.70	5.02	23.32
	99.83	99.11	99.29	99.05	100.06	100.22	99.36

	Wall rock chlorite Malpourchié	Vein-chlorite Roche Noire
SiO_2	31.72 quartz 8%	23.30
Al_2O_3	16.26	19.02
Fe_2O_3	12.05	10.75
FeO	23.32	27.80
TiO_2	0.59	0.03
MnO	0.63	0.61
MgO	4.89	7.98
CaO	0.19	0.15
Na_2O	0.20	0.20
K_2O	0.20	trace
P_2O_5	0.26	0.23
H_2O	9.13	10.57
	99.44	100.64

The vein chlorite has been calculated as ripidolite with a Fe (total) / Fe (total) + Mg ratio of 0.85 and a Si/Al (tetrahedral) ratio of 5.5 : 2.5. Ripidolites of similar composition have been described by Hallimond (1939) and Tschermak (1891) from the ore deposits of Cornwall. (the nomenclature is from Deer et al. 1962).

The optical data are also concurrent to those of ripidolite: N_α (yellow) : 1.646; N_γ (dark green) : 1.651; $N_\gamma - N_\alpha$: 0.005; – $2V_x$: 10°; anomalous interference colours are lacking.

Chlorite from the wall rock of the Malpourchié deposit has almost the same optical properties:

N_α (yellow) : 1.649; N_γ (dark green) : 1.654; $N_\gamma - N_\alpha$: 0.005; - $2V_x$: small (5°); anomalous interference colours are lacking.

The chemical analyses, however, seem to be different because of contamination, but after subtracting quartz, the chemical composition also comes very close to the chlorite of Roche Noire.

These highly ferroan chlorites are not incidental cases, but have been indentified in many instances where the grain size of chlorite has permitted an accurate determination of optical properties (v.d. Wart, 1959). They even have been noticed from calcite-epidote veins that result from retrograde metamorphism of the amphibolites.

Hence, the idea of Angel about the genesis of siderite and ankerite does not apply to the origin of the siderite of the Belledonne's Inner Zone, since the alteration products still possess remarkably high iron-contents. Moreover, the common presence of siderite in the Belledonne's Outer Zone, where iron-bearing silicate minerals do not occur in any significant quantity, is no more compatible with Angel's hypothesis.

25 Cinnabar

The occurrences of cinnabar in the Belledonne are interesting, since they reveal a certain relation between the ore deposits of Chalanches and the Alpine ores of the La Mure district. In the La Mure district cinnabar has been met in metalliferous veins in

Subtracted for those of goethite the reflections of the cryptomelane-like mineral are:

{hkl}	Hollandite II of India Byström, 1950		Coronadite of Bou Tazoult Frondel, 1942		Richesse, Savoy		
{20$\overline{2}$}	3.463	st.	3.466	st.	3.45	st.	
{103}	3.105	v. st.	3.104	v. st.	3.11	v. st.	
{211}	2.406	st.	2.400	st.	2.39	st.	
{204} {40$\overline{2}$}	2.198	st.	2.205	st.	2.21	st.	(broad)
{20$\overline{4}$} {310}	2.172	st.			2.17	st.	
{013}	2.146	st.	2.155	st.	2.14	st.	

The diagram confirmes the idea that we are dealing with one of the members of the cryptomelane-coronadite group. A definite identification only appeared to be possible by a chemical analyses. A sample has been prepared in the same way as happened for the X-ray analyses: 97 milligram was all the material that could be made available.

Fe_2O_3	28.0	goethite
H_2O + O	13.5	goethite
K_2O	1.3	cryptomelane
MnO	3.5	cryptomelane / coronadite
MnO_2	34.5	cryptomelane / coronadite
PbO	12.9	coronadite
res.	3.5	quartz
	97.2	

H_2O + O have been determined as loss on ignition. Fe_2O_3 has been precipitated by the acetate method. The combined manganese oxides were determined by precipitation of MnO_2 from a neutral solution by bromine water. The MnO : MnO_2 ratio has been calculated according to the coronadite (Pb) and the cryptomelane (K) composition. Pb has been determined as $PbSO_4$, the precipitate being identified by microchemical reactions (KI; CsCl: KI + CsCl) and sodium rhodizonate (for excluding Ba). Potassium has been separated by the sodium-cobalt-trinitrite method.

Thus, notwithstanding comtamination, coronadite (ideal composition: Pb Mn^{II} Mn_6^{IV} O_{16}) forms the bulk of the sample. Cryptomelane, apparently, also occurs. The ore-microscopical properties noticed by the author will not be mentioned here, because of the poor development of coronadite crystals in the investigated samples, and their identity with those from Bou Tazoult, where far more representative specimens occur (Orcel, 1932).

28 Dolomite

Dolomite, as a vein constituent, is known from the Grande Bois and Pont Rouge deposits. Its paragenetical relations are similar to those of ankerite from other veins in the Allemont ore

Fig. 47. Granoblastic recrystallization fabric of galena and sphalerite. Galena recrystallized to a coarser grain size than sphalerite. St. Hugon.

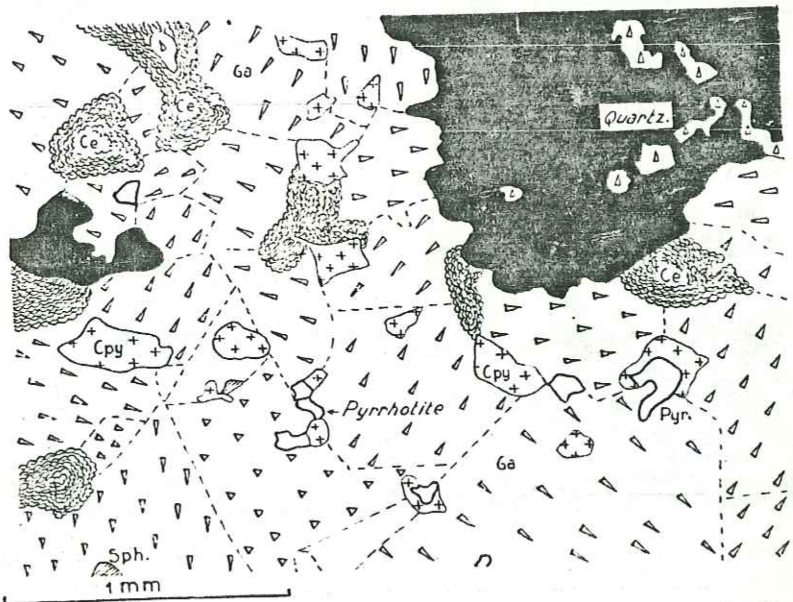


Fig. 48. Coarse recrystallization fabric of galena. Recrystallization occurred without major changes of chemistry, such as indicated by high Bi-content and the scattered presence of pyrrhotite (Pyr.) and chalcopyrite (Cpy). Supergene replacement by cerussite (Ce). Argentine.

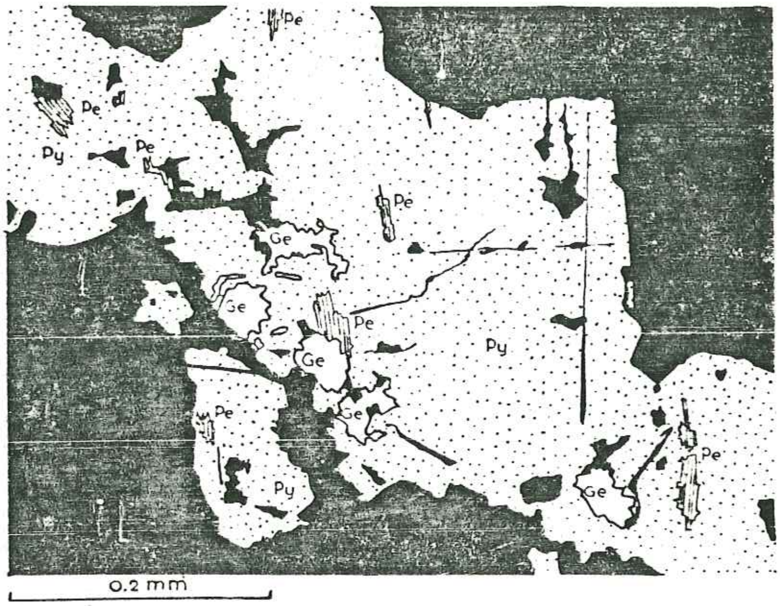


Fig. 49. Exsolution lamellae of spindle-shaped pentlandite (Pe) in pyrrhotite (Py). Gersdorffite (Ge) with "corroded" outlines. Replacement relics, or porphyroblastic growth? Argentine.

Fig. 50. Trains of small gersdorffite crystals (high relief) of euhedral outlines (cubo-octahedron-sections). Some gersdorffite crystals show cavities at their centres. Intricate intergrowths of tetrahedrite (dark gray) and chalcopyrite (light gray). Remoud. 100 x.

	%- Ag.	%- Bi
Montgilbert	not.det.	0.11
Les Mouches	0.14	0.03
Bonvillard	0.10	0.03
Argentine	0.08	0.19

The copper-contents are not recorded, since they vary widely and are due to chalcopyrite inclusions.

Some galena's have remarkably high Bi-contents, so high that they should be attributed to catathermal genesis, according to Schroll (1955) and Baumann (1958). Other Bi-contents, however, occurring in the same paragenesis are substantially lower. These differences cannot be attributed to recrystallization alone, since recrystallization occurred in all deposits. Apparently the disruption and subsequent entrapment by quartz has caused the galena to lose its bismuth-content, whereas the silver-content has hardly been affected by this process. Only galena from the younger vein type has also lost part of its silver (Longerolle, Pierre Herse).

A Pb-isotope determination has been performed by the F.O.M. laboratory for mass-separation. The results are listed below:

	Pb^{208}	Pb^{207}	Pb^{206}	Pb^{204}
50 Tilleray	52.50 ± 0.06%	21.23 ± 0.12%	24.96 ± 0.11%	1.313 ± 0.16%
85 Pierre Herse	52.71 ± 0.04%	21.16 ± 0.16%	24.84 ± 0.19%	1.294 ± 0.43%
20 Longerolle	52.43 ± 0.14%	21.25 ± 0.16%	25.01 ± 0.16%	1.318 ± 0.16%
7 Mont Jean	52.44 ± 0.12%	21.25 ± 0.19%	25.00 ± 0.16%	1.309 ± 0.36%
17 Le Sapey	52.38 ± 0.09%	21.21 ± 0.23%	25.10 ± 0.16%	1.309 ± 0.19%
102 Perrelle	52.49 ± 0.09%	21.22 ± 0.17%	24.98 ± 0.10%	1.311 ± 0.35%
103 Richesse	52.55 ± 0.08%	21.22 ± 0.11%	24.92 ± 0.12%	1.313 ± 0.43%
106 Montgilbert	52.45 ± 0.13%	21.23 ± 0.16%	25.04 ± 0.21%	1.289 ± 0.67%
108 Bonvillard	52.51 ± 0.11%	21.20 ± 0.28%	24.99 ± 0.12%	1.304 ± 0.62%
112 Argentine	52.38 ± 0.06%	21.32 ± 0.39%	24.97 ± 0.39%	1.329 ± 0.17%
104 Les Mouches	52.55 ± 0.21%	21.21 ± 0.31%	24.91 ± 0.25%	1.330 ± 0.40%
90 Fond de France	52.22 ± 0.09%	21.45 ± 0.18%	25.01 ± 0.10%	1.327 ± 0.47%
92 St. Hugon	52.49 ± 0.15%	21.21 ± 0.25%	24.98 ± 0.19%	1.325 ± 0.45%

	$\frac{Pb^{206}}{Pb^{204}}$ α	$\frac{Pb^{207}}{Pb^{204}}$ β	$\frac{Pb^{208}}{Pb^{204}}$ γ	$\Delta\beta / \Delta\alpha$	Age in Ma ± 75 Ma
Tilleray	19.012	16.170	39.985	0.6083	230
Pierre Herse	19.198	16.359	40.741	0.6162	316
Longerolle	18.974	16.115	39.768	0.6050	193
Mont Jean	19.107	16.238	40.077	0.6094	242
La Sapey	19.177	16.205	40.024	0.6015	153
Perrelle	19.051	16.180	40.022	0.6069	214
Richesse	18.973	16.156	40.011	0.6094	242
Montgilbert	19.424	16.469	40.687	0.6132	284
Bonvillard	19.160	16.254	40.260	0.6077	223
Argentine	18.784	16.037	39.406	0.6090	237
Les Mouches	18.736	15.948	39.521	0.6024	163
Fond de France	18.843	16.164	39.350	0.6188	344
St. Hugon	18.847	16.003	39.606	0.6012	149

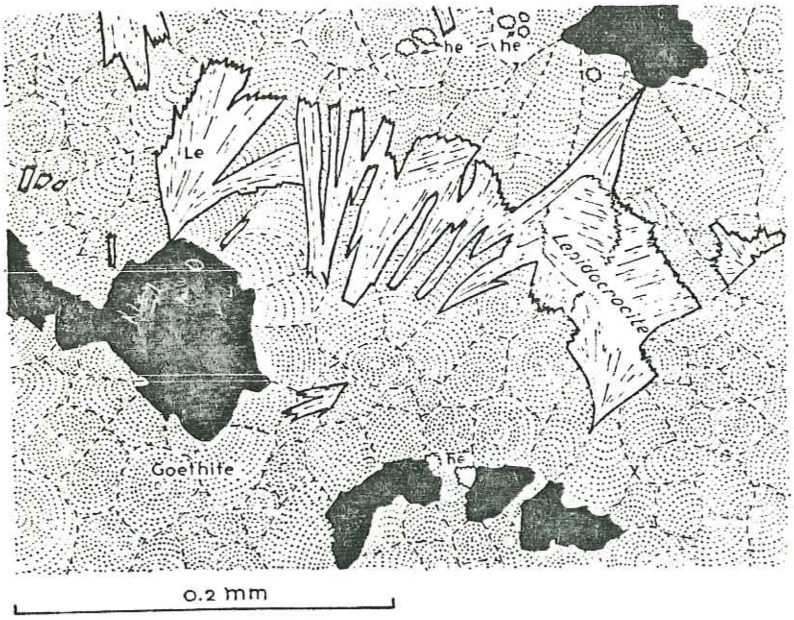


Fig. 51. Sheaf-like aggregates of lepidocrocite cut across botryoidally textured goethite (he = hematite). Rochefort.

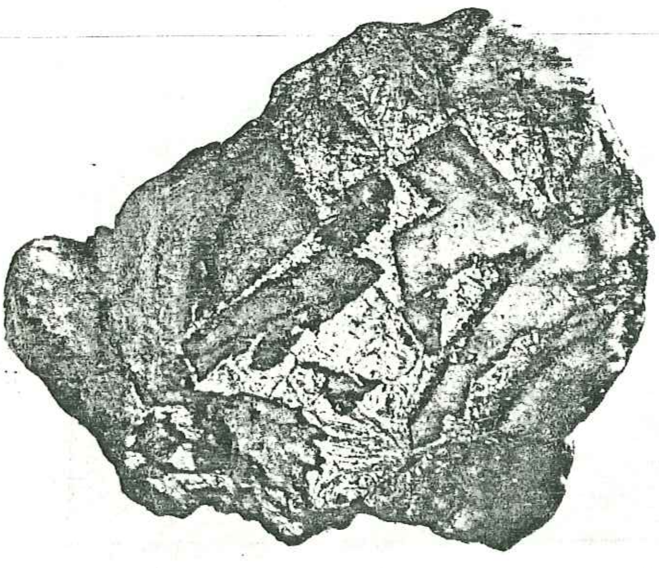


Fig. 52. Pseudomorphs of magnetite (high reflect.) after tabular hematite, filling the ankerite interstices (low reflect.). St. Charles, Allemont. 2 x.

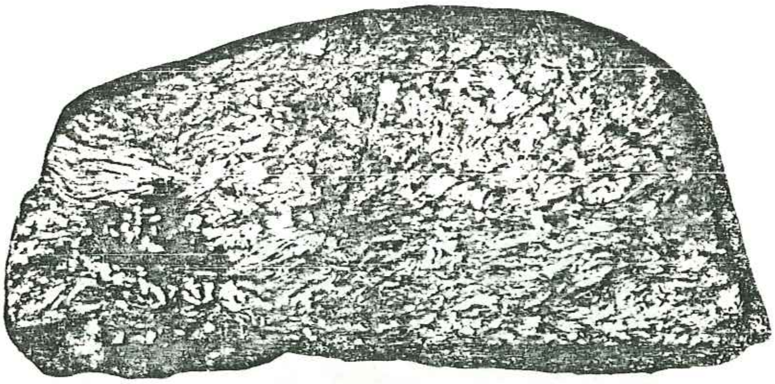


Fig. 53. Flakes of hematite embedded in calcite are replaced by euhedral magnetite, as shown by the etched part, where only magnetite has retained its reflectivety. Les Essarts. 2 x.

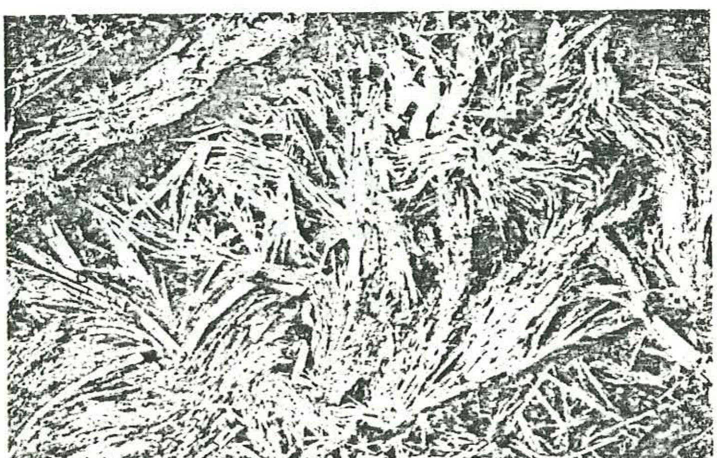


Fig. 54. "Folded" crystals of hematite. Tavernes. 3 x.

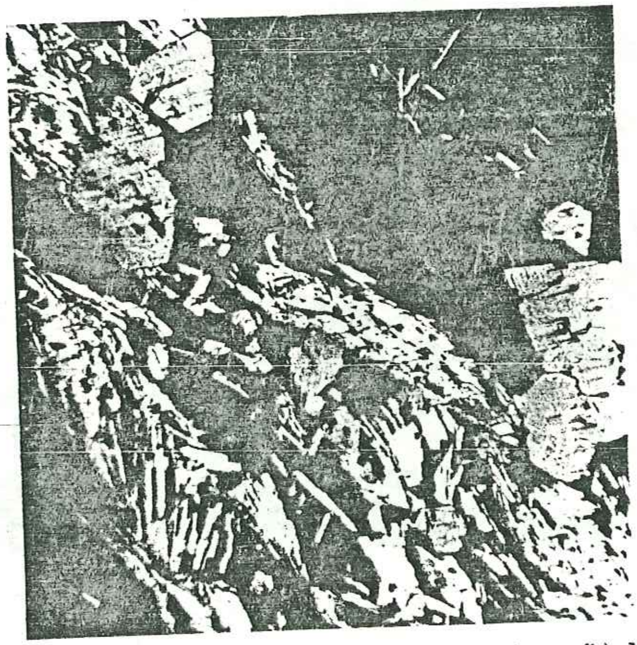


Fig. 55. Octahedrons of magnetite replace tabular hematite (highest refl.). Note martitisation of magnetite, 30 x.

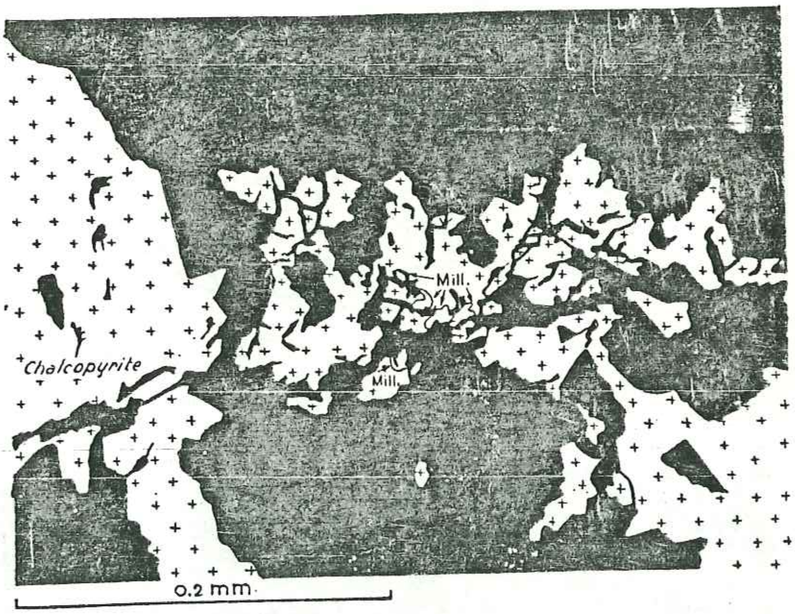


Fig. 56. Replacement of chalcopyrite by siderite (black) results into the formation of small millerite (mill.) crystals along the replacement borders. La Chevrette.

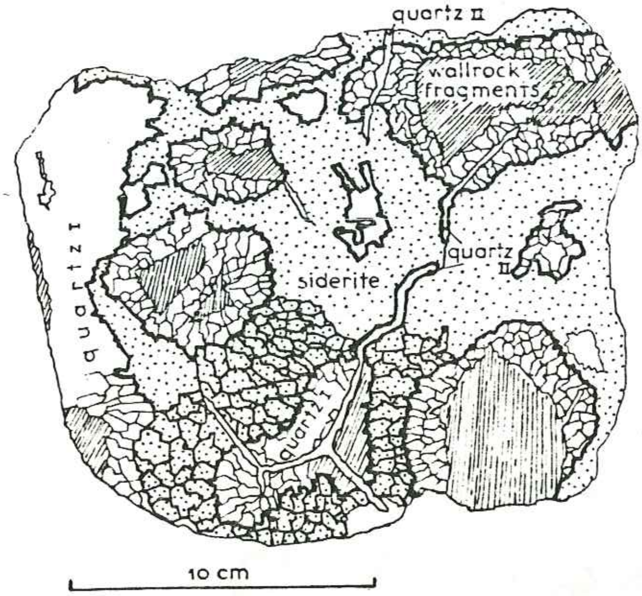


Fig. 57. Cockade ore. Concentric rings of quartz I around wall rock fragments, succeeded by intricately intergrown siderite. Both older formations are cut across by veins of quartz II. La Chevrette.

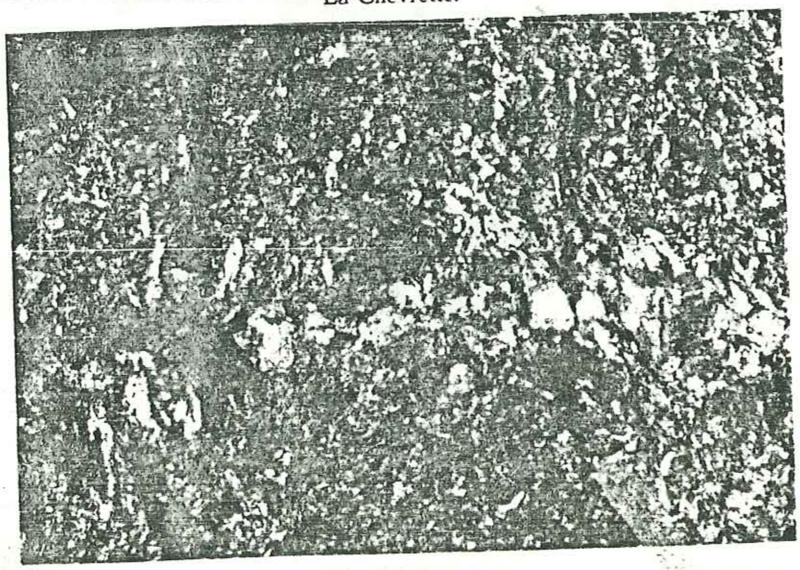


Fig. 58. Detail of siderite of La Chevrette, intricately intergrown fabric of fusiform crystals. La Chevrette, 2 x.

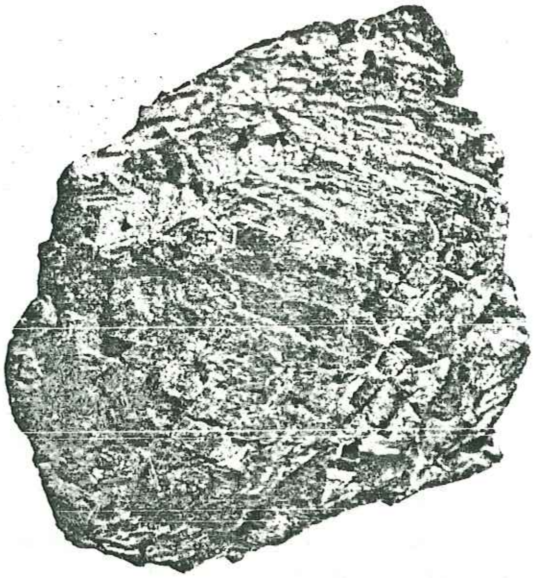


Fig. 59. Large rhombohedral crystals of siderite belonging to the younger mineralization. Le Merle, ²/₃ x.

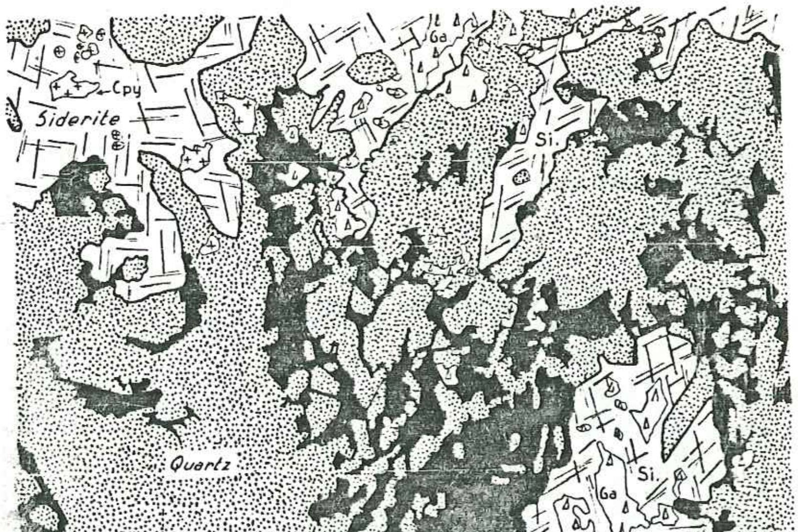


Fig. 60. Disperse sideritisation of walk rock fragments enclosed in the quartz vein of Sapey. Siderite replaces galena (Ga.) and chalcopyrite (Cpy.).

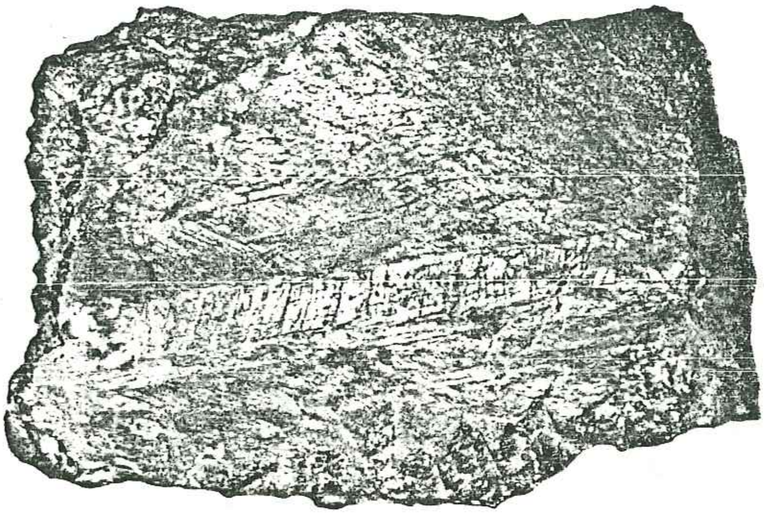


Fig. 61. Lamellar twinning of sphalerite as a result of deformation. Pierre Herse, 1 x.

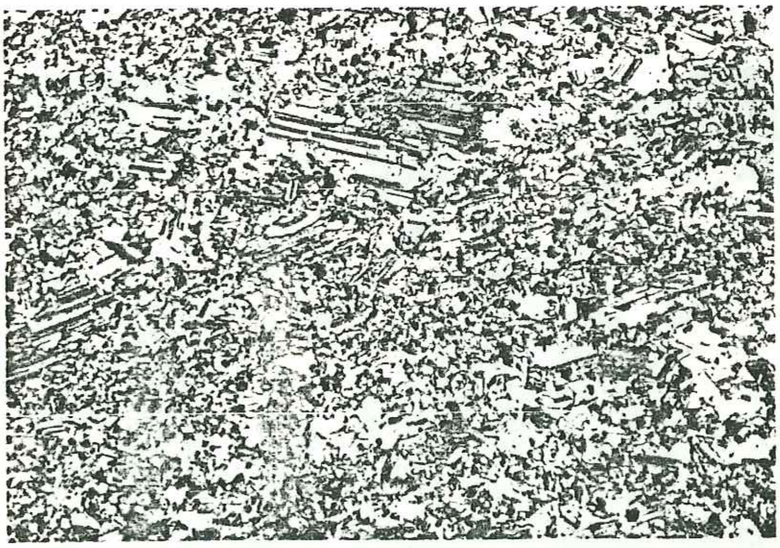


Fig. 62. Detail of figure 61, showing a fine grained recrystallization fabric of sphalerite, besides larger twinned crystals. Pierre Herse, 30 x.

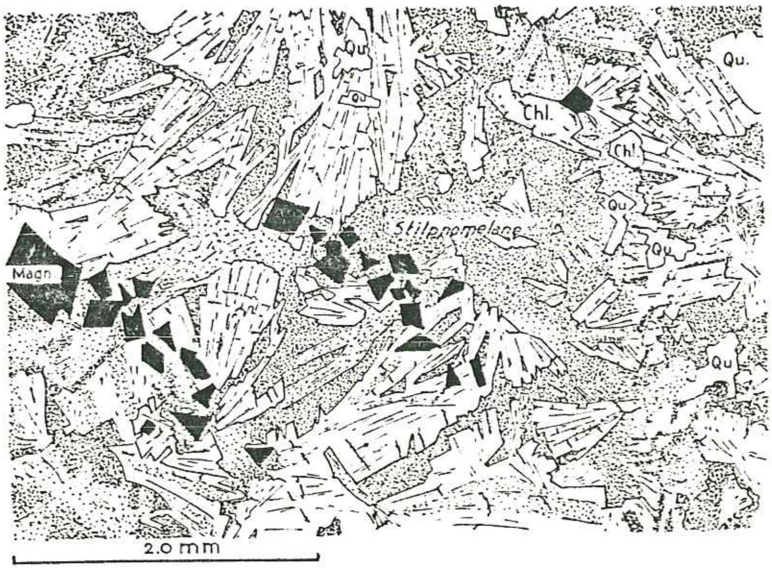


Fig. 63. Stilpnomelane (sheaf-like aggregates or basal sections), chlorite (Chl) and magnetite (Magn) as low grade metamorphic alteration products of siderite. Roche Noire.

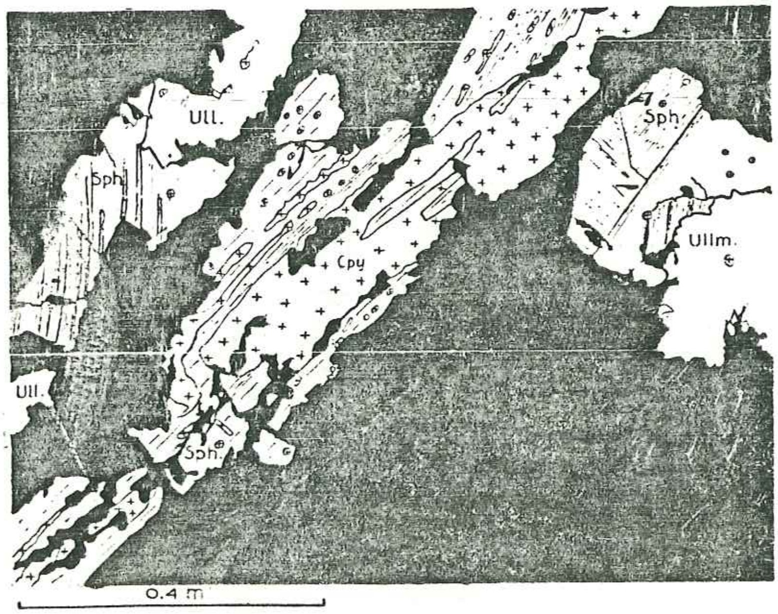


Fig. 64. Arbitrarily shaped ullmannite (Ullm) crystals are confined to the sulphide-streaks of the La Fayolle vein. Note intergrowths of sphalerite (Sph) and chalcopyrite (Cpy) and exsolution drops of chalcopyrite (crosses) in sphalerite.

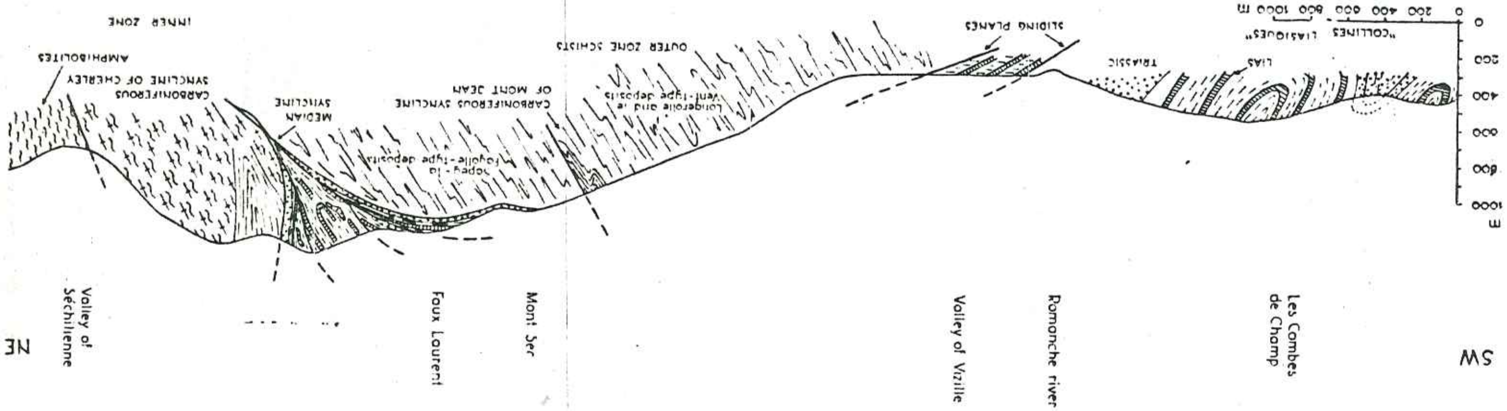


Fig. 65. Section through the Median Syncline and Carboniferous syncline of Mont Jean in the Vizille region, according to Moret (1952) and P. Lory (1948).

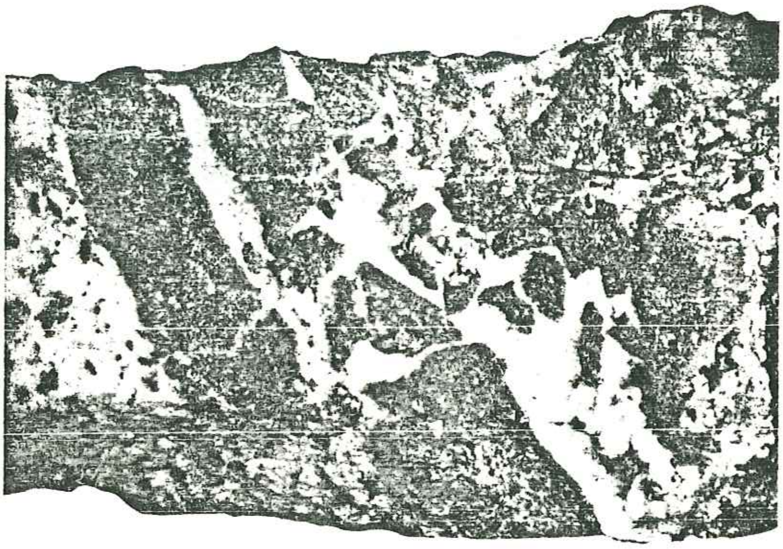


Fig. 66. Dispersely mineralized wall rock fragments have been disrupted by quartz I. Figure 60 represents a detail of such a mineralized wall rock fragment. Le Sapey, 1 x.

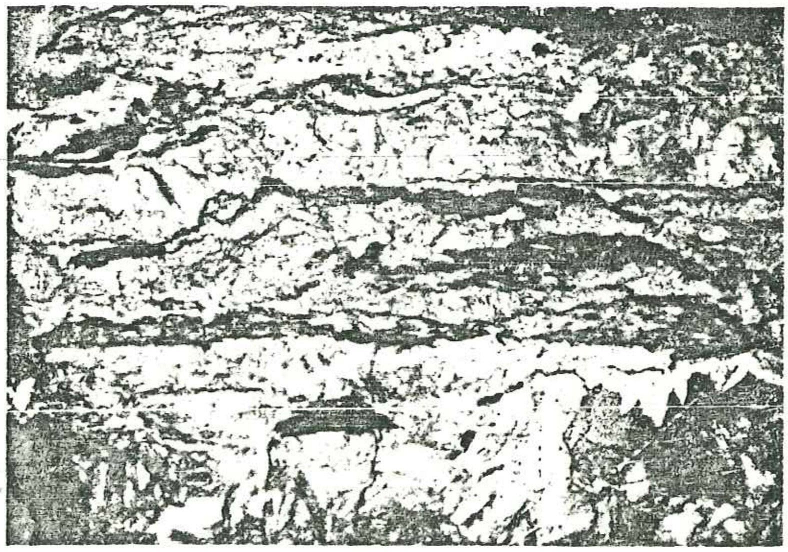


Fig. 67. Serratedly intergrown, fusiform siderite crystals, oriented perpendicularly to streaks (black) of wall rock. Grande Chambre, 1 x.

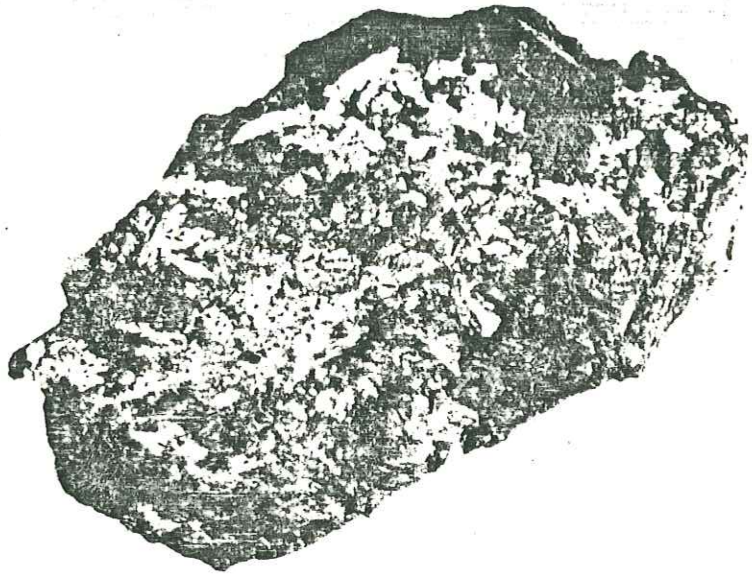


Fig. 68. Large euhedral crystals of siderite and ankerite (white) from the vug-like deposit of Le Vent. ½ x.

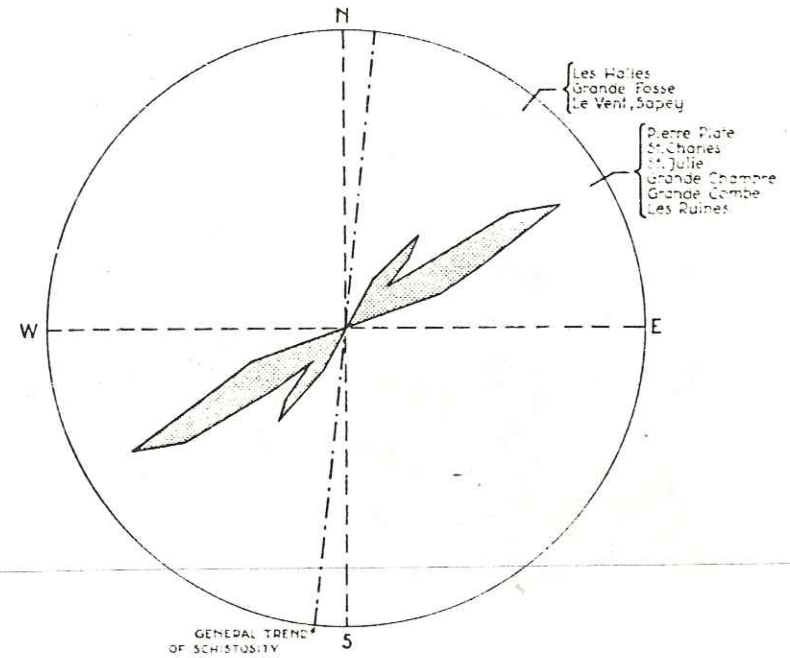


Fig. 69. Diagram of the strikes of the ore veins of the Vizille region, the strike of schistosity varies between N 5° E and N 20° E.

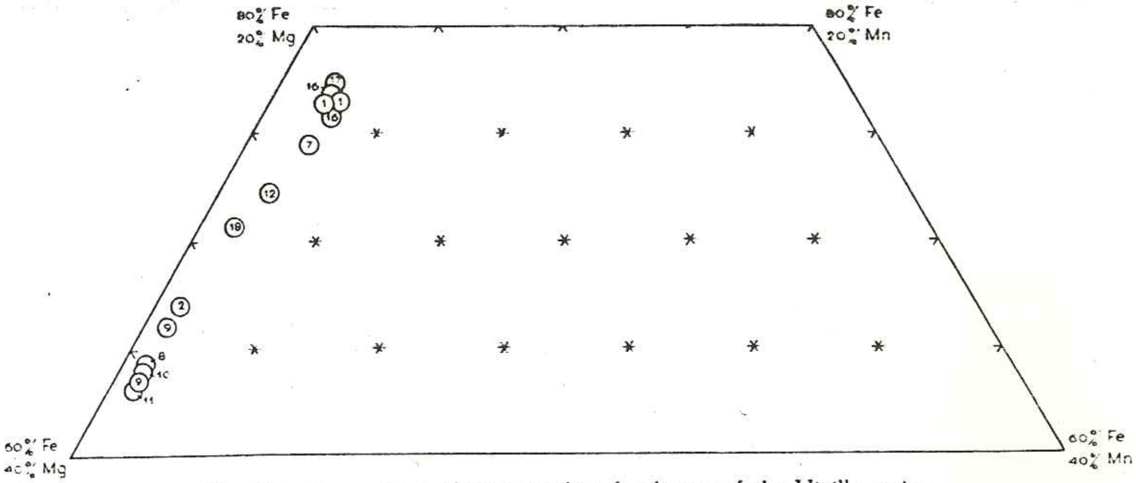


Fig. 70. Composition of the non-altered siderites of the Vizille region.

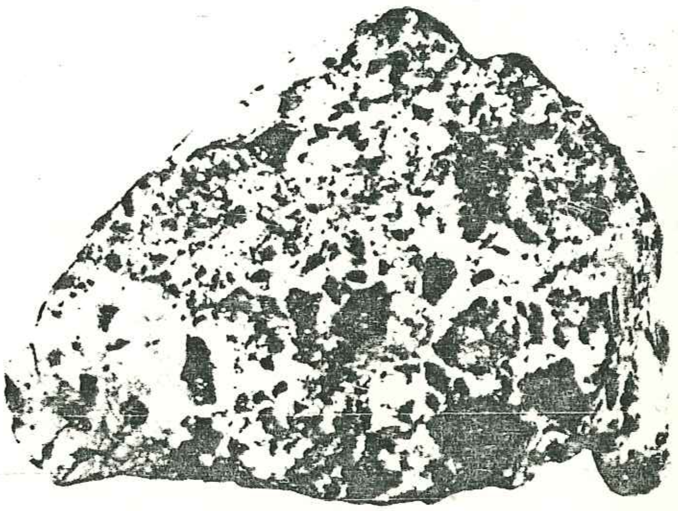


Fig. 71. Fragments of sphalerite broken down by, and embedded in quartz (light brown to yellow sphalerite). Le Sapey. 1 x.

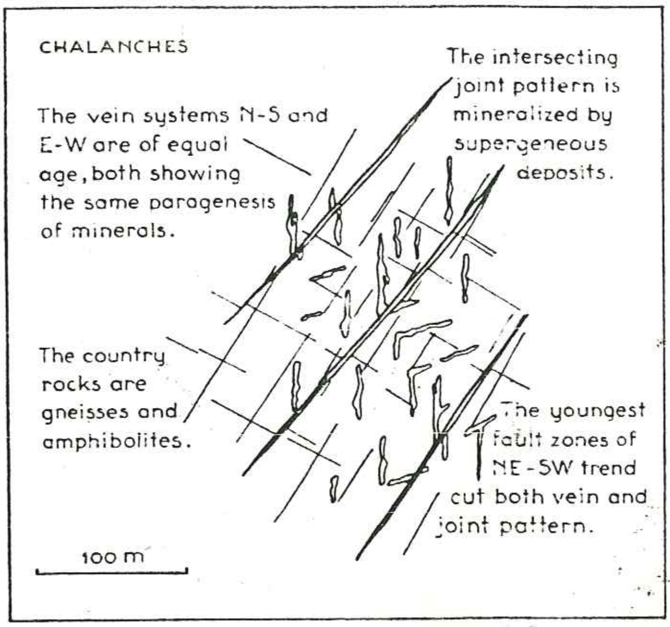


Fig. 72. Idealized representation of the mineralized joints and fault-breccias of Chalanches according to data of Hericart de Thury (1806), Gueymard (1844) and personal interpretation.

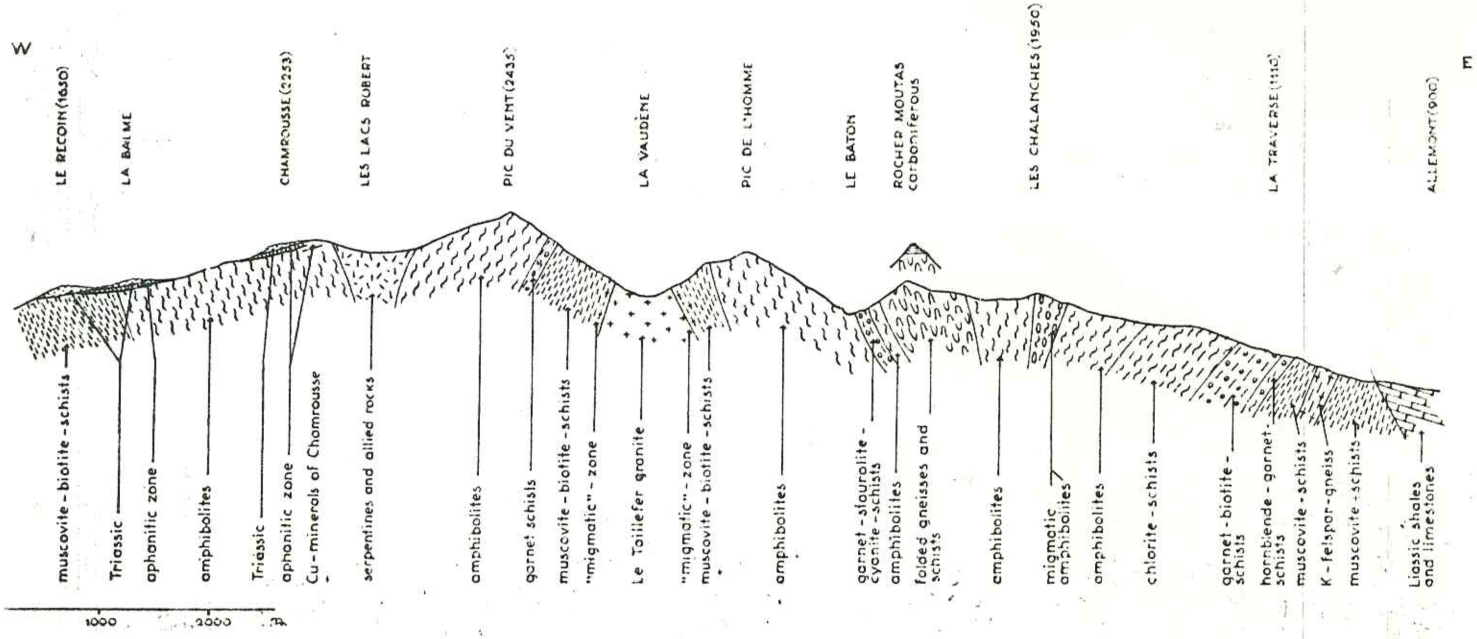


Fig. 73. Cross-section of the Allemont region, according to data of Den Tex (1950), Maron (1955), Michel (1958) and personal observations. The term "migmatic zone" of the Taillefer granite is of Michel, and denotes a schistose border zone of the granite.

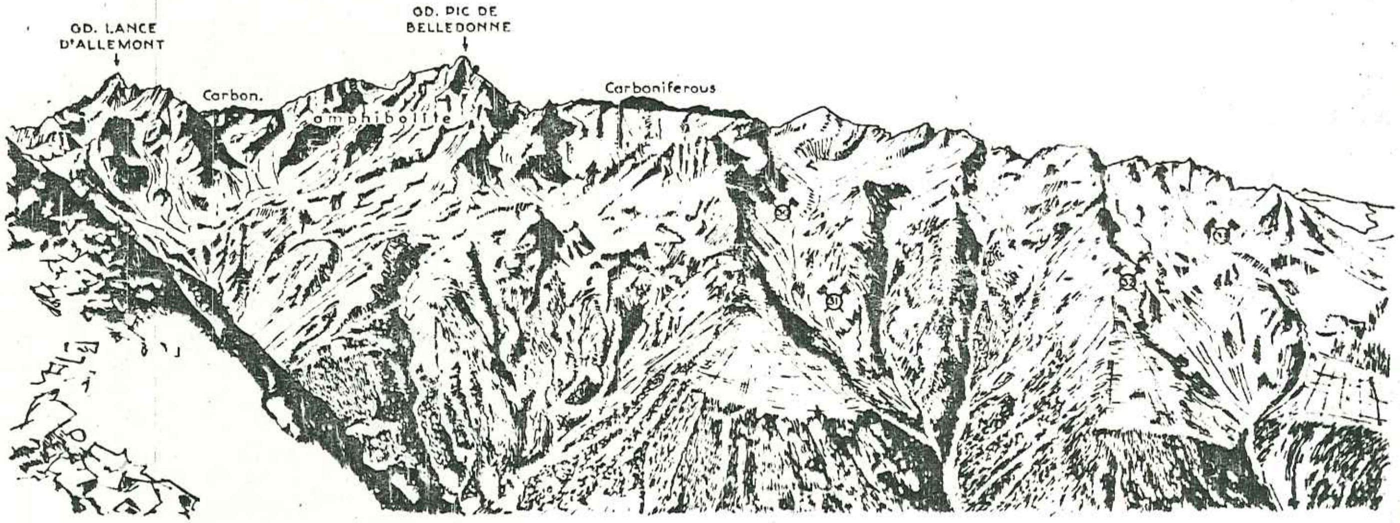


Fig. 74. View from the east to the central ridge of the Allemont region. The position of some siderite deposits and the almost horizontal Upper Carboniferous covers are indicated.

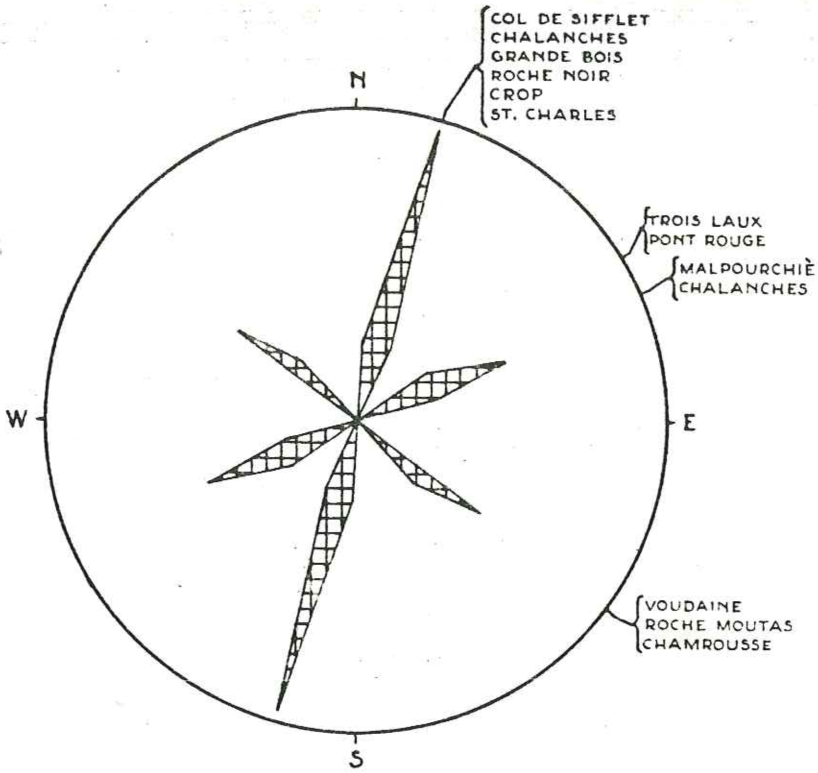


Fig. 75. Strike diagram of the ore veins of the Allemont region.

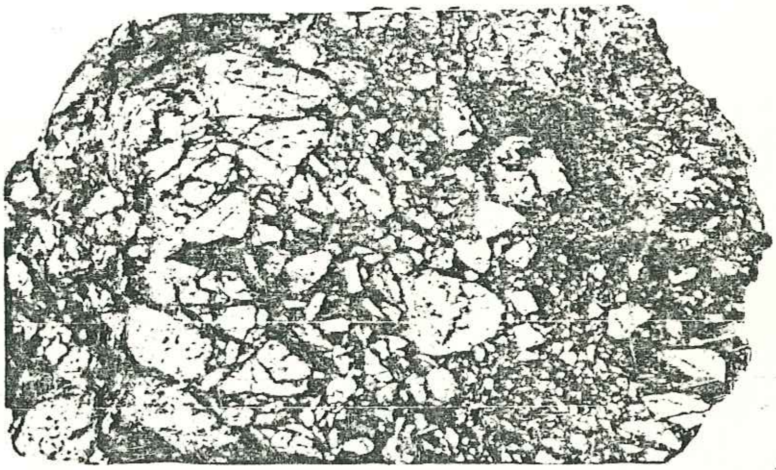


Fig. 77. Fault-breccia mineralized by ankerite of Grande Bois composition. Pont Rouge-Ruisson, 1 x.

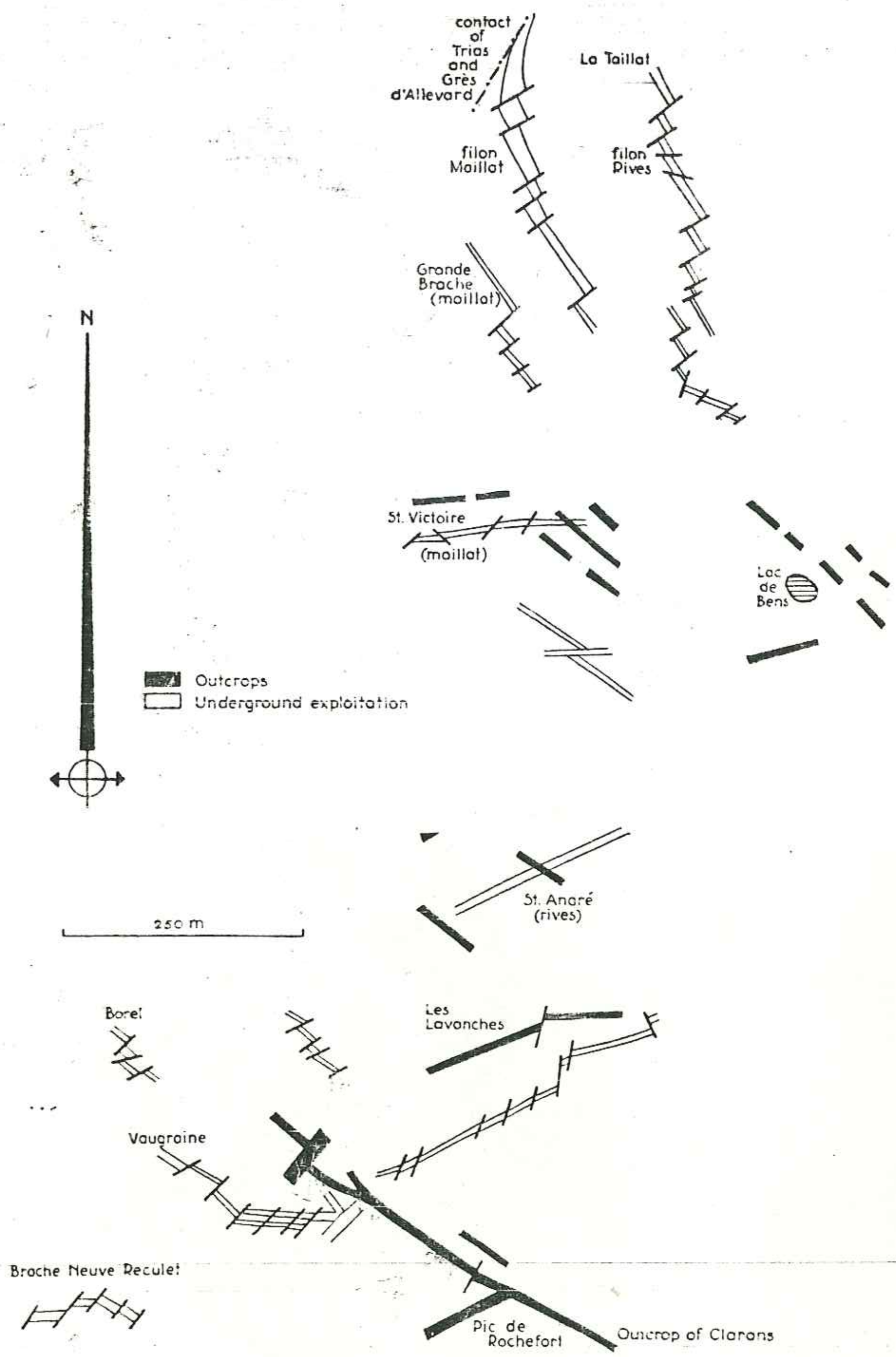


Fig. 78. Pattern of siderite veins of the Taillat area (Allevard ore district). The Taillat Maillat vein (younger ore suite) follows for some tens of metres the contact of Grès d'Allevard (Permian) and Triassic.

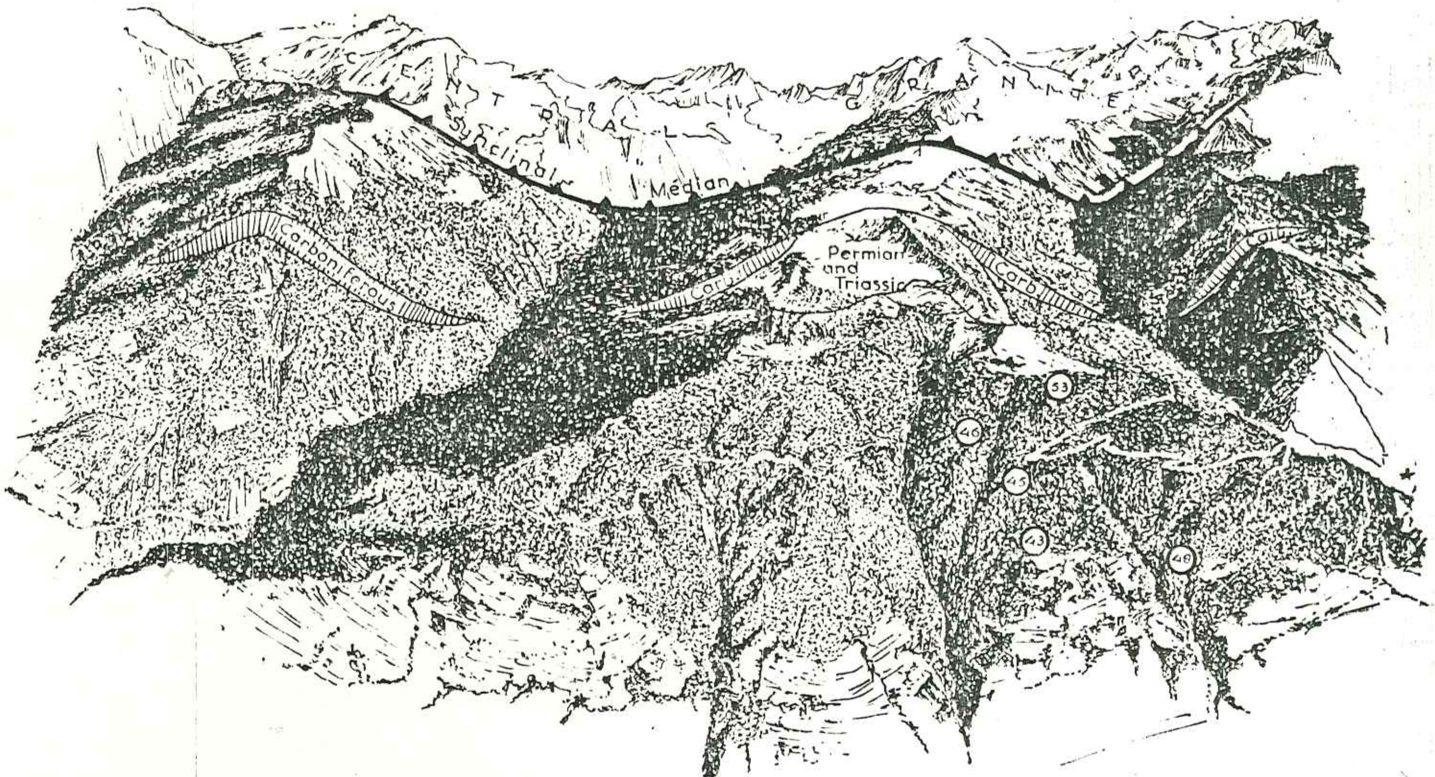


Fig. 79. View from the west to the northern part of the Allevard region and the southern part of the Aiguebelle region. Both are separated by the Carboniferous synclines of Prodin (the northern most wedge) and the Grand Collet (middle wedge). The numbers refer to the ore deposits.

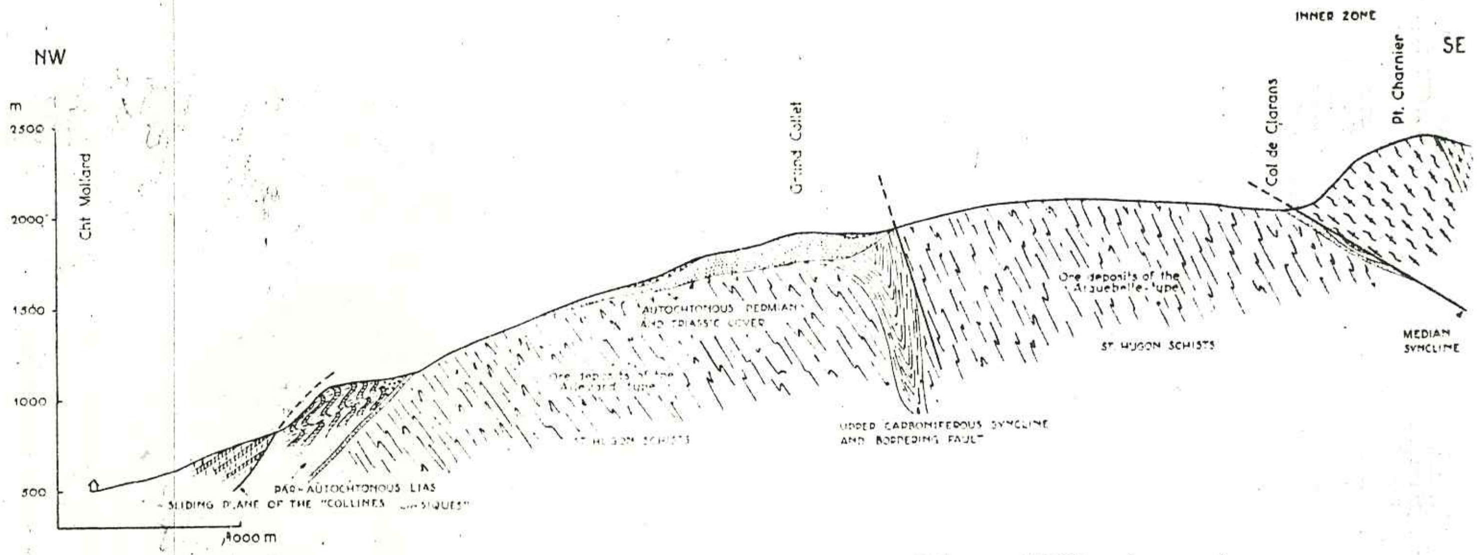


Fig. 80. Section through the Grand Collet. According to data of Touwen (1958) and personal observations.

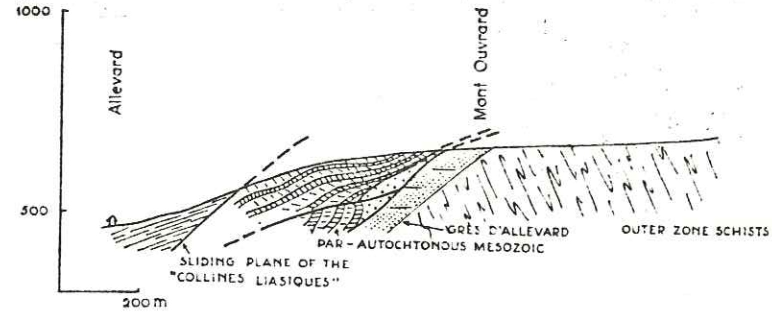


Fig. 81. Detail of the par-autochthonous Mesozoic cover such as displayed by the Bout du Monde gorge of the Bréda river. The formation marked by widely spaced dots represents the Triassic (gypsum, dolomites and limestones).

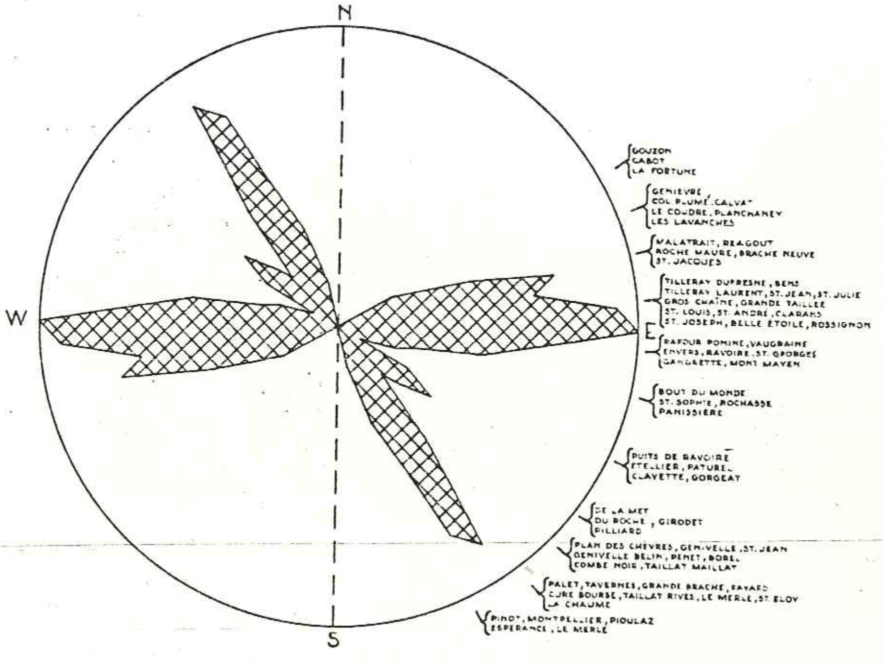


Fig. 82. Diagram of strikes of the ore veins of the Allevard region.

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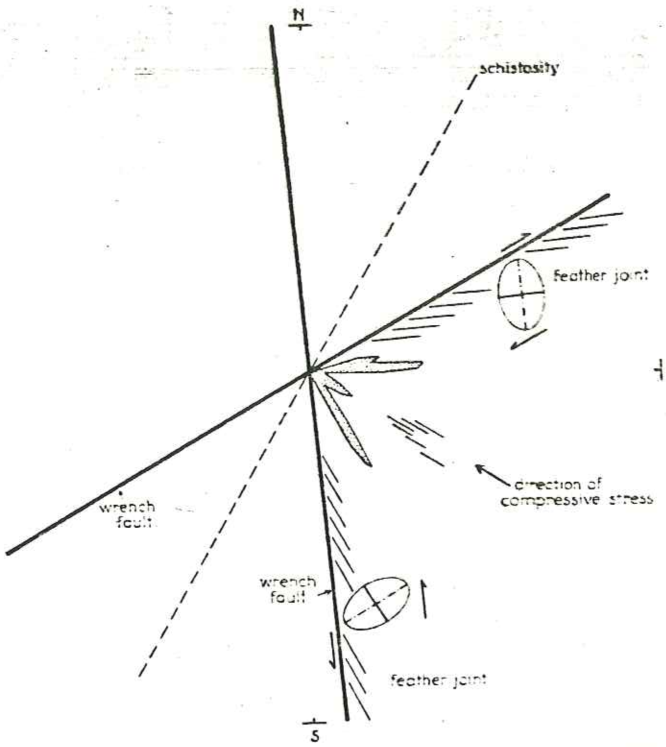

Fig. 83. The strikes of ore veins of the Allevard region as tension joints of the wrench fault system.

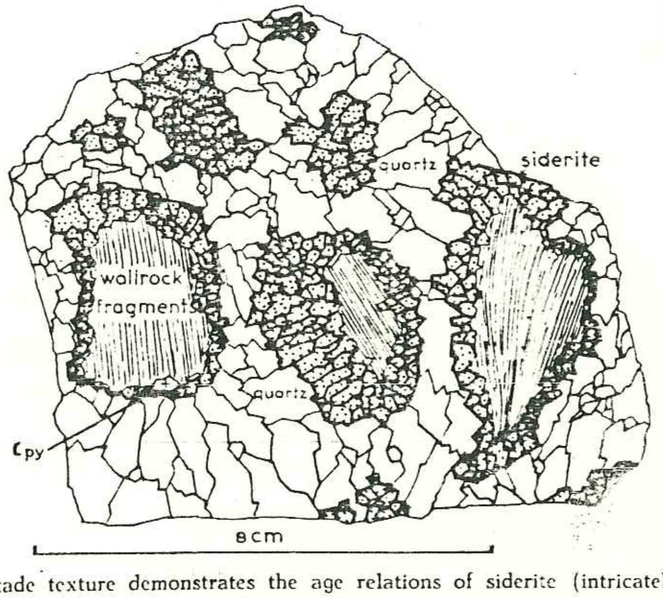

Fig. 84. Cockade texture demonstrates the age relations of siderite (intricately intergrown) and quartz. Cabot, 1 x.

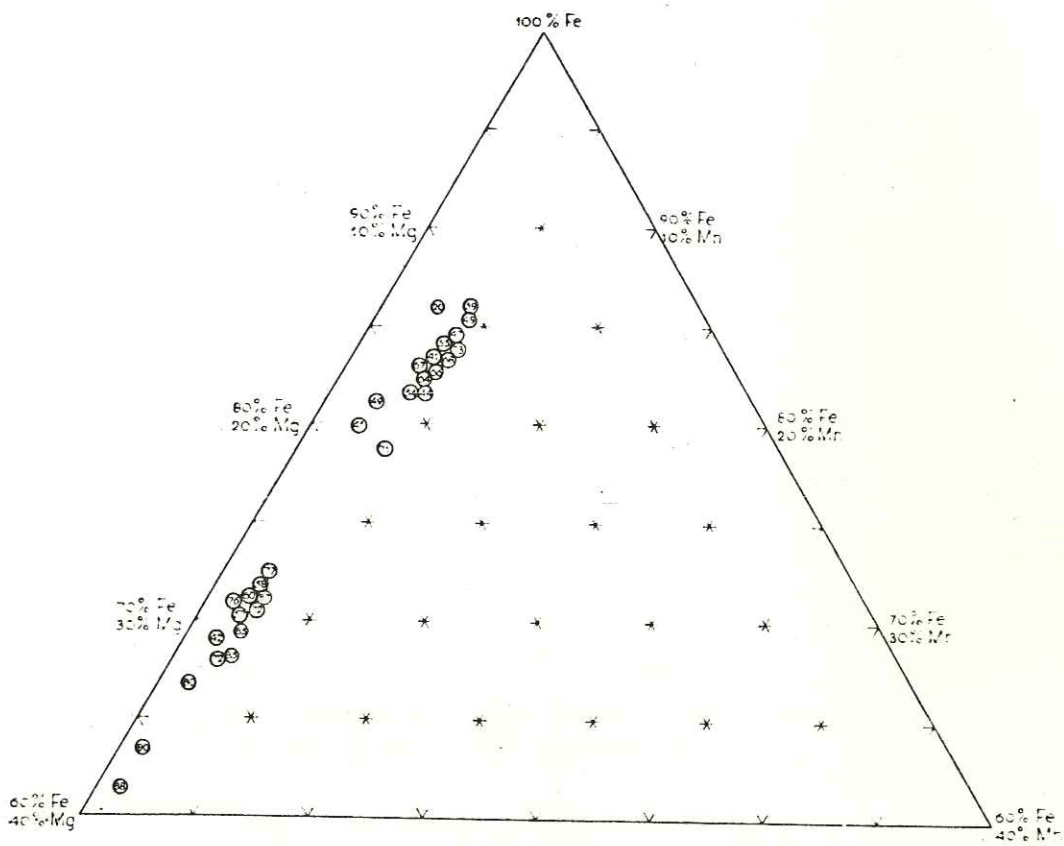

Fig. 85. Diagrammatical representation of the chemical composition of the siderite deposits of the Allevard region.

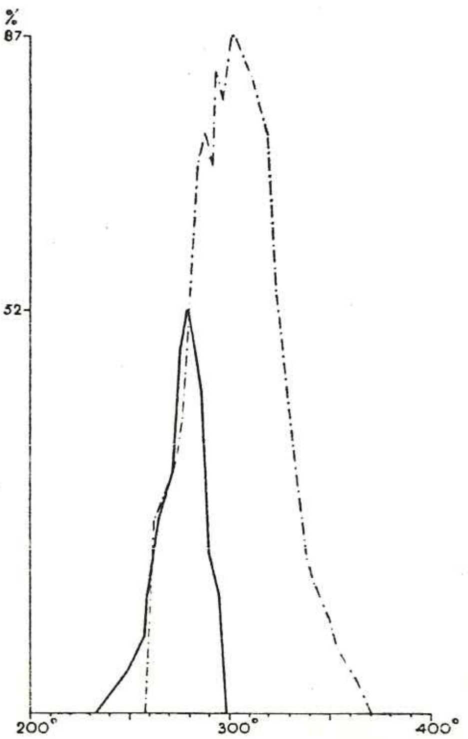

Fig. 86. Frequency of homogenization temperatures of the older and the younger (interrupted line) quartz formations of the Allevard region.

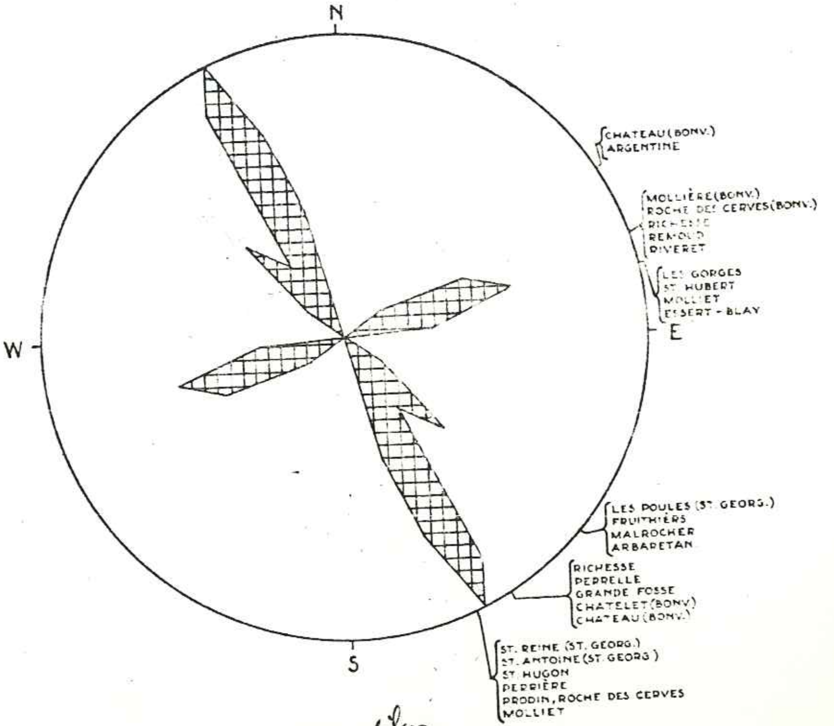

Fig. 87. Diagram of strikes (filon) of the Aiguebelle ore veins.

(Diagramme des filons d'Aiguebelle minéralisés)

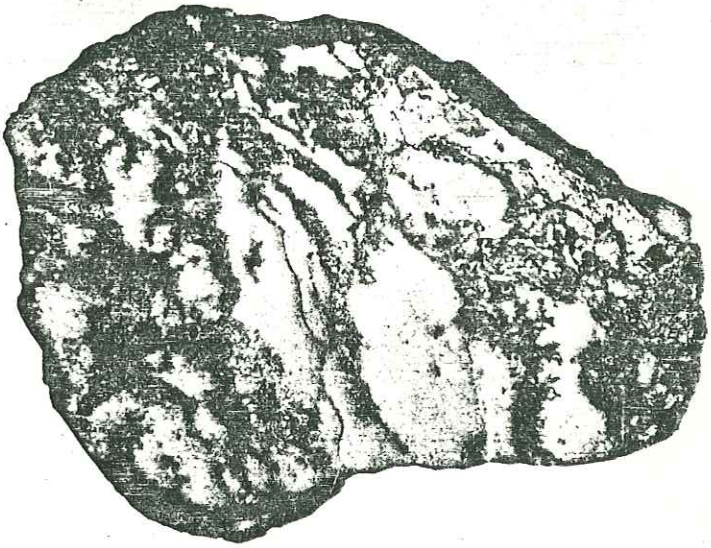

Fig. 88. Galena (high reflect.) and sphalerite (black) have been disrupted and dissected by quartz (white) into streaky fragments. Fosse Guerre, 1 x.

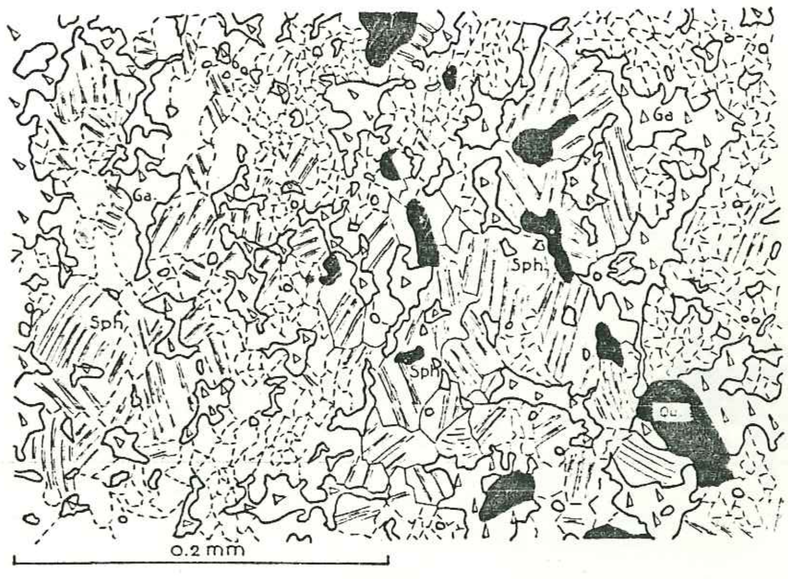

Fig. 89. Medium grained recrystallization fabric of galena (Ga) and sphalerite (Sph). Malrocher.

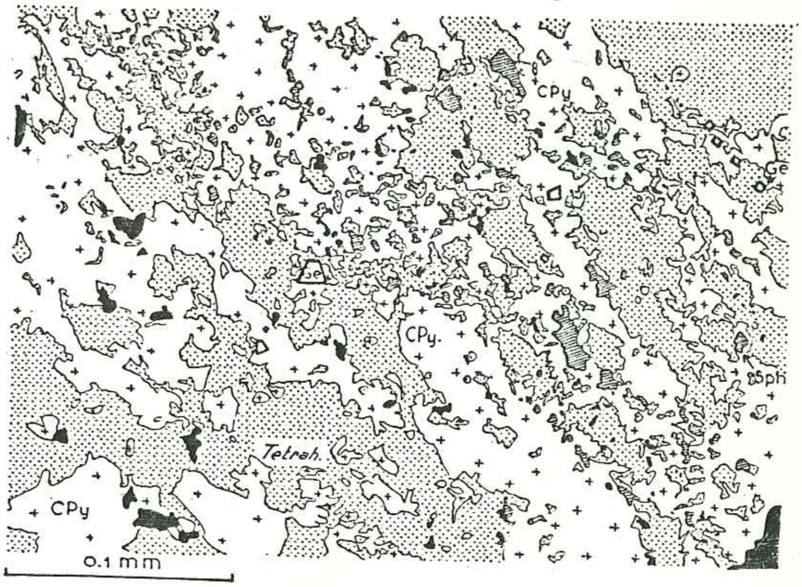

Fig. 90. Intricate intergrowths of tetrahedrite (tetrah.), chalcopyrite (Cpy) and sphalerite (shaded). Fine grained recrystallization fabric grown after strong deformation (roll-ore). Note trains of euhedral gersdorffite crystals (Ge). Remoud.

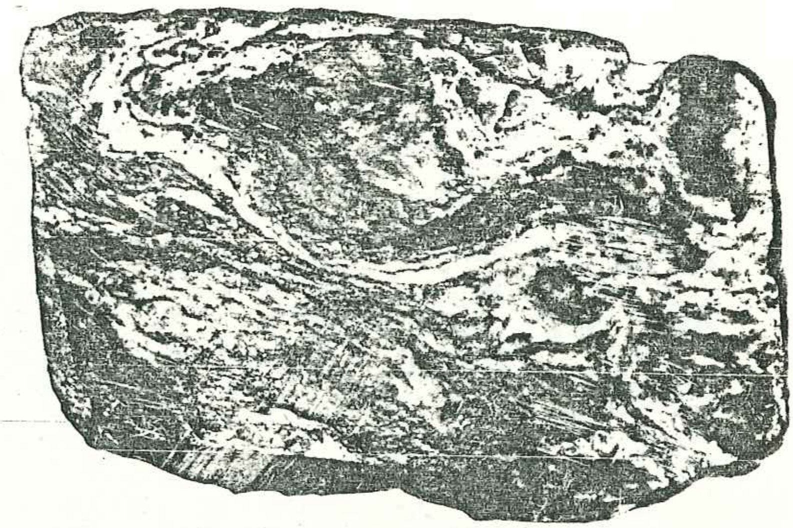

Fig. 91. Highly deformed barite-sulphide vein of Bonvillard (barite is white, sulphides are grey or reflecting spots), 2 x.

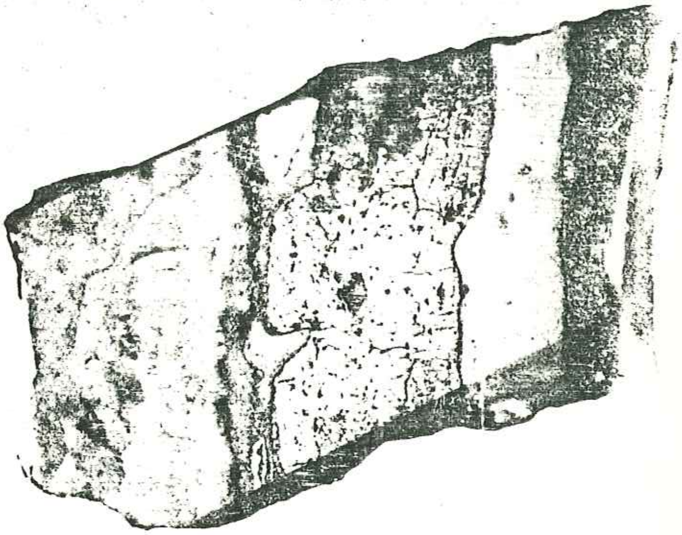

Fig. 92. Streched sphalerite (reflect.) vein embedded in barite (white). Bonvillard, 2 x.

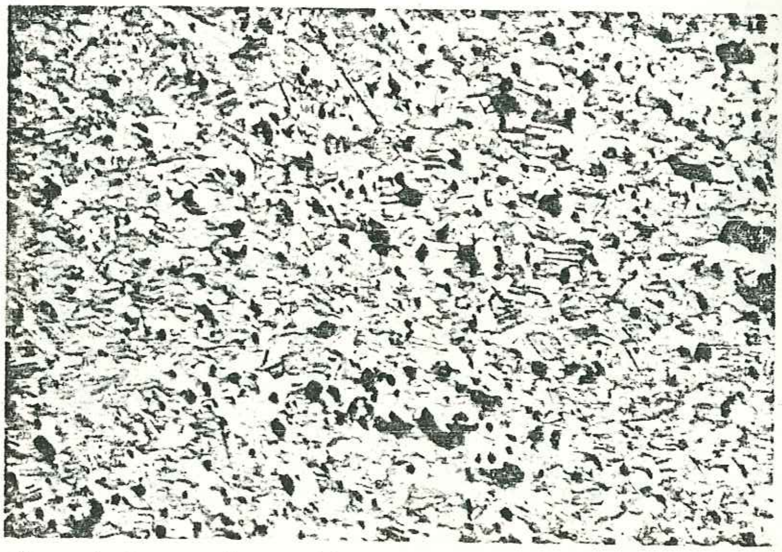

Fig. 93. Fine-grained recrystallization fabric of sphalerite of Bonvillard, detail of figure 92, etched by HI. 150 x.

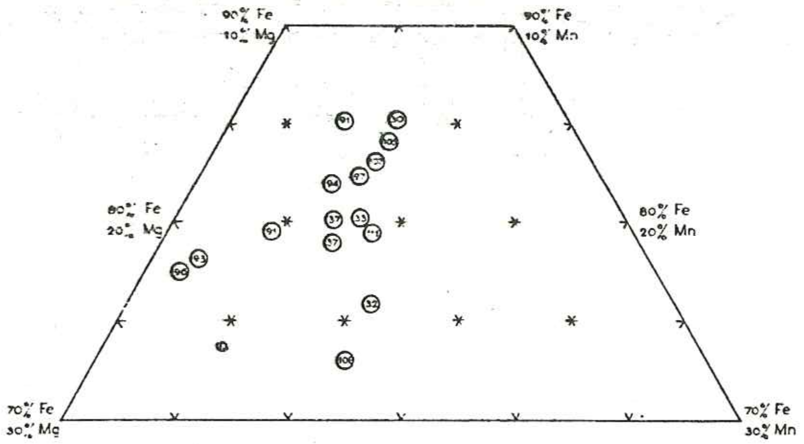

Fig. 94. Diagram representing the chemical compositions of siderites of the Allemont and Aiguebelle regions.

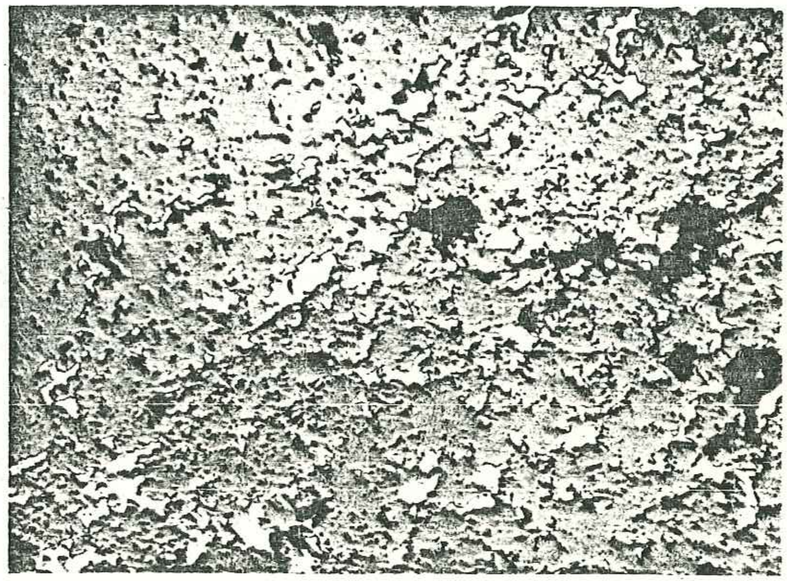

Fig. 95. Intergrowths of sphalerite (gray) and galena (white). Where sphalerite occurs in excess over galena, recrystallization is rare. Malrocher, 200 x.

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The study of the ore deposits of the Allevard region started in 1953 as part of the petrological investigations of the Belledonne Range by Prof.Dr. E. Niggli (Bern), at that time chairman of the petrological department of the Leiden Geological and Mineralogical Institute. In 1955, when Prof.Dr. W.P. de Roever (Amsterdam) succeeded Prof. Niggli the investigations of the ore deposits were extended by the author to the whole Belledonne, whereby much help was offered by Prof.Dr. L. Moret and his staff of the Grenoble Geological Institute. The permission given by Mr. Moreau to make free use of the maps of the archives of the "Société des Hauts-Fourneaux et des Forges d'Allevard" was of great value for locating the ore deposits of the Allevard region. The author owes many informations about ore occurrences to the petrological studies on the Belledonne by the Leiden group, such as made by Mr. A.J.A. Janse, Mr. P. Maron, Mr. N.A.L. Touwen and Mr. R. v.d. Wart. Besides by them, samples have also been provided by Dr. P.C. Zwaan of the "Rijksmuseum voor Geologie en Mineralogie", Dr. C.O. van Regteren Altena and Mr. J.R. Möckel of the "Teylers Museum" at Haarlem and Mr. J. Lannes (Froges, Isère).

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LIST OF ORE OCCURRENCES

Name	Number	Position	Maps
André (St.)	- 69-	346.4 ; 892.8	Allevard
Allevard	- 42-	349.6 ; 893,2	Allevard
Alloues (les	- 9-	317.6 ; 874.2	Vizille
Argentine	-112-	363.2 ; 912.6	Aiguebelle
Beauregard	- 31-	327.5 ; 888.8	Allemont
Bonvillard	-108-	373 ; 913	Bonvillard
Cabot	- 67-	346.9 ; 893.8	Allevard
Chalanches	- 23-	321.7 ; 887.5	Allemont
Chamrousse	- 27-	320.1 ; 880.8	Vizille
Chaume (la)	- 73-	347.3 ; 893.0	Allevard
Charles (St.)	- 2-	314.3 ; 872.1	Vizille
Charles (St.)	- 34-	330.4 ; 889.5	Allemont and Fond de France
Chevrette (la)	- 91-	347.7 ; 897.5	Allevard and Aiguebelle
Clavette	- 52-	350.7 ; 894.7	Allevard
Col de Sifflet	- 35-	330.3 ; 889,3	Allemont and Fond de France
Combe Noire	- 64-	347.6 ; 893.7	Allevard
Coudre (le)	- 84-	340.9 ; 890.5	Fond de France
Crop (Lac du)	- 37-	328.3 ; 885.8	Allemont
Cuchet	- 58-	348.6 ; 893.1	Allevard
De la Met	- 51-	350.5 ; 894.4	Allevard
Doua (le)	- 95-	354.6 ; 901.5	Aiguebelle
Du Rocher	- 62-	348.1 ; 893.4	Allevard
Envers	- 44-	351.3 ; 894.8	Allevard
Espérance	- 59-	348.4 ; 893.4	Allevard
Essarts (les)	- 38-	337.5 ; 891.7	Fond de France
Esserts-Blay	-111-	377.5 ; 918.4	Bonvillard
Etellier	- 57-	348.6 ; 893.5	Allevard
Fare (la)	- 25-	322 ; 866	Allemont
Fayolle (la)	- 21-	305 ; 871.5	Geological map
Feuillette (la)	- 76-	344.2 ; 890.4	Allevard
Fond de France	- 90-	337.5 ; 894	Fond de France
Fortune (la)	- 68-	346.7 ; 893.4	Allevard
Fosse Guerre	-101-	360.5 ; 903.2	Aiguebelle
Fruithiers (les)	- 97-	359.4 ; 901.3	Aiguebelle
Gangrette	- 65-	347.4 ; 893.5	Allevard
Genivelle	- 78-	342.6 ; 891.0	Allevard
Georges des Hurt.(St.)	-105-	364 ; 907	Aiguebelle
Girodet	- 81-	342.3 ; 892.2	Allevard
Gorges (les)	-107-	359.1 ; 906.2	Aiguebelle
Grande Bois	- 29-	324.2 ; 890.3	Allemont
Grande Chambre	- 16-	312.5 ; 873.2	Vizille
Grande Combe	- 6-	314.7 ; 872.5	Vizille
Grande Roche	- 36-	330.5 ; 893	Fond de France
Grande Taillée	- 49-	351.0 ; 894.3	Allevard
Gros Chêne	- 48-	351.0 ; 894,0	Allevard
Halles (les)	- 9-	317.6 ; 874.2	Vizille
Hugon (St.)	- 92-	351.4 ; 899.8	Allevard and Aiguebelle
Jacques (St.)	- 47-	351.4 ; 894.3	Allevard
Jasse (Lac de la)	- 87-	333.8 ; 889.3	Fonde de France
Joseph (st.)	- 45-	351.3 ; 894.9	Allevard
Julie (St.)	- 5-	near Gd.Fosse	Vizille
Lac Crop	- 37-	328.3 ; 885.8	Allemont
Lac de la Jasse	- 87-	333.8 ; 889.3	Fond de France
Longerolle	- 20-	309.5 ; 871.9	Geological map
Malatrait	- 53-	350.6 ; 895.1	Allevard
Malpourchié	- 32-	327.5 ; 888.9	Allemont
Malrocher	- 98-	357.1 ; 902.1	Aiguebelle
Marameille	- 61-	347.8 ; 893.3	Allevard
Merdaret	- 86-	338 ; 889	Fond de France
Merle (le)	- 80-	342.0 ; 890.2	Allevard
Met (de la)	- 51-	350.5 ; 894.4	Allevard
Molliet	- 88-	355.9 ; 897.7	Aiguebelle
Montchaffrey	- 11-	317.3 ; 874.3	Vizille

Name	Number	Position	Map
Montgilbert	-106-	364 ; 907	Aiguebelle
Mont Jean	- 7-	315.1 ; 872.9	Vizille
Mouches (les)	-104-	363.6 ; 906.3	Aiguebelle
Oliver	- 10-	317.5 ; 874,4	Vizille
Panissière	- 56-	349.0 ; 893.6	Allevard
Parc (le)	- 12-	313.1 ; 871.1	Vizille
Paturel	- 79-	342.7 ; 891.0	Allevard
Paul (St.)	-110-	374.5 ; 919.5	Bonvillard
Perrelle	-102-	362.2 ; 804.0	Aiguebelle
Perrière	- 96-	351.9 ; 901.3	Aiguebelle
Peyrère (Peyreire)	- 20-	309.5 ; 871.9	Geological map
Pierre de Mésage (St.)	- 15-	near the village	
Pierre Herse	- 85-	337.4 ; 889.2	Fond de France
Pierre Plâte	- 1-	314.4 ; 871.9	Vizille
Pierre Rousse	- 14-	312.1 ; 871.7	Vizille
Pilliard	- 66-	347.3 ; 893.5	Allevard
Pioulaz	- 77-	343.7 ; 890.4	Allevard
Plan de Chèvre	- 63-	348.2 ; 893.8	Allevard
Pomine	- 70-	346.3 ; 892.8	Allevard
Pont Rouge	- 24-	320.7 ; 888.2	Allemont
Prévieux	- 99-	358.0 ; 901.6	Aiguebelle
Prodin	- 94-	355.8 ; 899.9	Aiguebelle
Rafour	- 43-	351.4 ; 894.8	Allevard
Ravoire	- 54-	349.8 ; 894.2	Allevard
Reagout	- 46-	351.3 ; 895.0	Allevard
Remoud	- 93-	355.4 ; 900.5	Aiguebelle
Richesse	-103-	359.2 ; 903.7	Aiguebelle
Rochefort	- 74-	345.3 ; 892.7	Allevard
Roche Moutas	- 26-	322.6 ; 886.8	Allemont
Roche Noire	- 30-	327.0 ; 888.2	Allemont
Rocher (du)	- 62-	348.1 ; 893.4	Allevard
Rossignon	- 60-	348.1 ; 893.2	Allevard
Ruines (les)	- 18-	312.3 ; 873.7	Vizille
Ruisson (Pont Rouge)	- 24-	320.7 ; 888.2	Allemont
Sapey (le)	- 17-	310.5 ; 873.9	Vizille
Sophie (St.)	- 55-	349.3 ; 893.4	Allevard
St. André	- 69-	346.4 ; 892.8	Allevard
St. Charles	- 2-	314.3 ; 872.1	Vizille
St. Charles	- 34-	330.4 ; 889.5	Allemont and Fond de France
St. Georges des Hurt.	-105-	364 ; 907	Aiguebelle
St. Hugon	- 92-	351.4 ; 899.8	Aiguebelle
St. Jacques	- 47-	351.4 ; 894.3	Allevard
St. Joseph	- 45-	351.3 ; 894.9	Allevard
St. Paul	-110-	374.5 ; 919.5	Bonvillard
St. Pierre de Mésage	- 15-	near the village	
St. Sophie	- 55-	349.3 ; 893.4	Allevard
Taillat de l'Oule	- 98-	357.1 ; 902.1	Aiguebelle
Taillat maillat	- 72-	346.9 ; 892.7	Allevard
Taillat rives	- 71-	347.2 ; 892.8	Allevard
Tavernes	- 75-	344.7 ; 892.5	Allevard
Tilleray	- 50-	350.6 ; 893.7	Allevard
Trois Laux	- 33-	329.1 ; 888.5	Allemont and Fond de France
Vaudaine	- 28-	321.8 ; 882.9	Allemont
Vaujalaz	- 83-	338.8 ; 891.9	Fond de France
Vent (le)	- 8-	315.3 ; 873.1	Vizille
Vernay	- 13-	313.3 ; 871.7	Vizille
Violettes (les)	- 82-	340 ; 891	Fond de France
Voudène	- 28-	321.8 ; 882.9	Allemont

Op verzoek van de Faculteit der Wis- en Natuurkunde volgt hier een kort overzicht van de academische studie van de schrijver.

In 1948 werd hij ingeschreven als student in de Faculteit der Wis- en Natuurkunde aan de Rijksuniversiteit te Leiden. Het kandidaatsexamen I werd afgelegd in 1951, het doctoraal examen Geologie in 1955. De studie stond onder leiding van de hoogleraren Dr. B.G. Escher, Dr. E. Niggli, Dr. L.U. de Sitter en Dr. I.M. van der Vlerk. Voor het doctoraal examen werd een chemische en mineralogische beschrijving gemaakt van een deel van de ertsen van het Belledonne Massief in de Franse Alpen, welk onderzoek in 1955 werd uitgebreid tot de gehele Belledonne.

In 1955 werd hij verbonden aan het Geologisch en Mineralogisch Instituut der Rijksuniversiteit te Leiden als assistent van prof. Dr. W.P. de Roever, in 1959 als wetenschappelijk ambtenaar bij de Afdeling van Prof. Dr. E. den Tex met als opdracht het geven van onderwijs in de mineralogie en erts-microscopie en de assistentie bij de leiding van het petrologisch veldwerk in N.W. Spanje.

In 1959 werd hij door het Departement van Onderwijs, Kunsten en Wetenschappen en de U.S. Atomic Energy Commission in de gelegenheid gesteld een cursus te volgen in de geologie van uraniumertsen in de Verenigde Staten van Amerika.

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PART I METHODS OF INVESTIGATION page

CHAPTER 1 THE FLUID INCLUSION THERMOMETRY

A geological map of the Belledonne Range has been inserted in the backflap of the cover

RÉSUMÉ

Les résulats de ces recherches comprennent:

- une interprétation génétique des inclusions fluides contenant du CO_2.
- une contribution à la géochemie et à la minéralogie de la province metallogénique de la Belledonne.
- une étude du processus de régénération des gîtes métallifères

On a cru jusqu'à présent que les inclusions fluides contenant du CO_2 n'étaient pas propres à servir de thermomètre géologique (Yermakov, 1957). Ceci implique, au fond, que fort peu d'inclusions pourraient entrer en ligne de compte pour cette application, puisque Deicha (1955) a montré que de nombreuses inclusions réagissent par un dégagement de gaz à l'essai par écrasement, bien qu'une phase riche en CO_2 n'ait pu être démontrée au microscope par la condensation d'anhydride carbonique. Une transposition du système CO_2-H_2O sur le plan théorique, basée sur les transitions des phases dans les inclusions, et les données physiques de Kennedy (1950, 1954), de Khitarov et de Malinin (1956, 1958, 1959) ont permis d'utiliser également des inclusions, qui contiennent du CO_2 pour une thermométrie de la cristallization. Les résultats sont traduits par des diagrammes appelés isochores (fig. 28, 32 et 33), qui indiquent le changement de temperatures et de pression pour une certaines proportion de CO_2 : H_2O à volume constant. La direction des courbes isochores détermine si la phase riche en CO_2 s'homogénéisera en phase fluide ou en phase liquide à la temperature critique du CO_2 (31° C). L'extrapolation de ces isochores en dehors de la limite de deux phases permet l'application de corrections de pression pour une thermométrie absolute. La lecture des diagrammes tridimensionnels de température de pression, et de volume (fig. 26 et 29) permet de déduire la degré critique de remplissage pour une certaine composition.

L'examen des inclusions a démonstré que les deux phases de minéralization, qu'on peut distinguer à base minéralogique et à base chemique, se sont développées à deux époques géologiques différentes. Il est permis de dater le minéralisation plus anciennes comme Hercynienne pour les raisons suivantes:

- le rapport des isotopes de plomb accuse un âge Houiller ou Permien,
- les gisements sont métamorphosées,
- il y a une certaine disposition zonale par rapport au granite central Hercynien, allent des paragénèses cata-thermales à des paragénèses mésothermales,
- Les minerais se sont deposés en diaclases d'extension appartenant à des failles transversales de déchrochement d'origine Hercynienne, qui se sont développées à même temps que la consolidation du granite central.

La jeune minéralization est sans doute d'âge alpin; la présence des minérais dans des formations Secondaires et dans des plans de failles alpines en fait preuve, ainsi que le fait que le position de la pénéplaine Triasique détermine la densité des inclusions riches en CO_2. La densité est moindre près de cette pénéplaine qu'a une certaine distance.

Après avoir démontré que le minéralisation de la Belledonne s'est accomplie en deux phases géologiques, il est remarkable de

constater que le contenu minéralogique de ces deux phases est indentique (quoique dans un ordre de cristallisation inverse), et qu'il existe un certain rapport entre les compositions chimiques des sidéroses les plus jeunes et les plus anciennes. La teneur en manganèse est diminuée de moitié à peu près, indépendamment de la teneur originale. Ces congruences s'expliquent par la régénération Alpine d'un gîte Hercynien. La différence, qui exists entre les vraies températures de cristallisation de la jeune minéralisation telles qu'elles sont indiquées par les temperatures de homogénéisation des inclusions (300° ± 30°), et la temperature de cristallisation qui est généralement attribuée à la paragénèse épithermale, est une confirmation de l'idée de régénération.