

CRYSTAL CHEMISTRY OF CORRENSITE: A REVIEW

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Abstract—Statistical analyses of chemical data from the literature of corrensite minerals suggest a large compositional variability, more evident in octahedral than in tetrahedral coordination. Mg occupies 40–80% of the octahedral sites, with Al and Fe²⁺ making up the remainder. Approximately 15–30% of the tetrahedral sites are filled by Al. Despite this compositional variability, distinct fields for the several types of mixed-layer trioctahedral chlorite/trioctahedral swelling layer are not apparent. Statistical analyses of the composition of corrensite compared with saponite, vermiculite, and chlorite suggest that corrensite is an intermediate between trioctahedral chlorite and trioctahedral smectite. If Fe/(Fe + Mg) > 50%, chlorite alone is favored, but with increasing Mg, chlorite appears to transform into corrensite and then, by iron oxidation, into trioctahedral smectite. Despite the chemical variability between corrensite, chlorite, and saponite, corrensite appears chemically to be a well-defined species. On the other hand, corrensite cannot be characterized chemically on the basis of its swelling component. Thus, the current definition of corrensite as a regular 1:1 interstratification of trioctahedral chlorite and either trioctahedral smectite or vermiculite is appropriate.

Key Words—Chemical composition, Corrensite, Mixed layer, Smectite, Statistical analysis, Vermiculite.

INTRODUCTION

Clay minerals which yield an X-ray powder diffraction (XRD) reflection at 32 Å with ethylene glycol or glycerol treatment have been described from a number of genetic environments. Lippmann (1954) gave the name corrensite to one of these materials and defined it as a regular 1:1 interstratified trioctahedral chlorite/swelling chlorite mineral. He subsequently referred to the swelling component as vermiculite (Lippmann, 1956), and later as “expandable layers” (Lippmann, 1957, 1976; Lippmann and Johns, 1969). The existence of a “chlorite/swelling layer interstratification” is now generally accepted, but the swelling component is still not well characterized, mainly because of its variable behavior in standard solvation and heating treatments (Lippmann, 1954, 1956, 1976; Bradley and Weaver, 1956; Earley *et al.*, 1956; Sudo and Kodama, 1957; Alietti, 1957a, 1957b; Martin Vivaldi and MacEwan, 1960; Sugiura, 1962; Almon *et al.*, 1976; April, 1980; Churchman, 1980).

The XRD features of this material can be summarized as follows: the untreated material gives rise to a reflection at 29–31 Å; after the sample is treated with ethylene glycol, this reflection expands to 31–33 Å; after the sample is heated to 550°C the reflection collapses to 23–28 Å (Bailey *et al.*, 1982). The thermal behavior of this material has also been widely investigated, but the data are difficult to use because the experiments were commonly insufficiently detailed. Usually the chloritic component is suggested by endothermic peaks at 500–600°C and 810–950°C, whereas endothermic peaks at 200°C are assigned to the swelling component (Mackenzie, 1972). A review of

chemical analyses from the literature also shows a large compositional range for the swelling component of so-called corrensites.

Based on the different nature of the swelling component, several definitions of corrensite have been proposed. In particular, Galan and Doval (1977) suggested retaining the name corrensite for a regular interstratification of chlorite/saponite only and assigning two new, distinct names to the regular interstratification of chlorite/swelling chlorite and chlorite/vermiculite. The Nomenclature Committee of The Clay Minerals Society, however, defined corrensite as a 1:1 regular interstratification of trioctahedral chlorite with either trioctahedral smectite or trioctahedral vermiculite (Bailey *et al.*, 1982).

A literature review of so-called corrensites shows a large variability in the crystal-chemical features of these materials. In particular, it is not clear, from the chemical point of view, whether all of the so-called corrensites described in literature can be considered as a single mineralogical species. The aim of the present study was to assess the variability of the crystal-chemical features of the materials described in literature as corrensite and to distinguish, if possible, different compositional ranges for the various materials that have been reported.

EXPERIMENTAL

Chemical analyses (Table 1) and *b* dimensions (Table 2) of corrensite materials were selected from the literature. Only the analyses where the authors stated the type and degree of impurities present were considered, and among these, only those where the mineral

Table 1. Source and chemical analyses of selected corrensites.

Sample ¹	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	TiO ₂	MnO	CaO	MgO	Na ₂ O	K ₂ O	H ₂ O-	H ₂ O+	Reference
1 C/Sap	36.12	13.67	2.14	6.85	0.23		1.70	25.16	0.37	0.10	4.81	9.25	Alietti (1957a)
2 C/Sap	39.04	15.32	13.86	5.57			0.30	25.23	0.68				April (1981)
3 C/Sap	30.38	24.21	0.11	2.34		0.13	0.15	26.31	0.29	0.08	1.93	13.31	Shirozu <i>et al.</i> (1975)
4 C/Sap	32.20	18.10	0.23	1.03		0.06	0.18	31.79	0.10	0.13	2.66	13.28	Shirozu <i>et al.</i> (1975)
5 C/Sap	33.28	21.61	0.66	1.11		0.21	2.52	23.23	tr	0.33	5.48	11.57	Shirozu <i>et al.</i> (1975)
6 C/Sap	34.33	14.94	0.15	0.63		0.04	0.33	32.19	0.11	0.20	3.67	13.18	Shirozu <i>et al.</i> (1975)
7 C/M	43.1	16.6	6.32		0.73	0.03	0.94	17.65	0.52	2.72		7.40	Earley <i>et al.</i> (1956)
8 C/V	32.96	17.07	2.79	8.68	0.47		0.58	23.01	0.58	0.16	2.63	11.28	Alietti (1957b)
9 C/V	39.45	14.16	21.97	9.85			0.73	13.15	0.68				April (1980)
10 C/V	41.20	12.1	1.74	0.39	0.04		1.4	22.0	0.07	0.22	6.80	15.4	Bradley and Weaver (1956)
11 C/M	42.19	17.00	8.98	7.43		0.20	1.98	21.38	0.32	0.51			Blatter <i>et al.</i> (1973)
12 C/Sap	33.44	14.33	1.66	3.68		0.16	2.83	22.44	0.16	tr	5.50	8.16	Mongiorgi and Morandi (1970)
13 C/Sap	36.7	9.1	10.6	2.3	0.1		2.20	21.7	0.4	0.2	9.5	8.10	Kimbara and Shimoda (1972)
14 C/Sap	35.73	14.05	7.17	7.22	0.11	0.11	3.49	18.44	1.20	0.15	4.09	7.80	Kimbara and Shimoda (1972)
15 C/Sap	34.72	13.94	11.45	4.14	0.57	0.20	3.37	16.61	1.43	0.30	5.69	8.34	Kimbara (1975)
16 C/Sap	35.59	15.13	6.65	9.15	0.30	0.38	1.86	14.76	1.13	1.13	6.62	7.30	Kimbara (1975)
17 C/V	33.90	17.60	10.92	1.20			1.10	20.98	0.67	0.68	2.92	9.83	Gallitelli (1956)
18 C/Sap	33.57	13.60	8.38	11.31	0.59	0.26	2.20	12.93	1.00	0.80	5.68	9.68	Kimbara (1975)
19 C/Sap	31.91	14.63	16.45	4.41	0.77	0.25	2.74	11.56	1.65	0.65	4.90	10.47	Kimbara (1975)
20 C/Sap	35.73	14.05	7.17	7.22	0.11	0.11	3.49	18.44	1.20	0.15	4.09	7.80	Kimbara (1975)
21 C/Sap	34.65	16.09	1.61	1.30	0.34	0.07	0.77	20.97	0.52	0.10	6.58	10.88	Kimbara (1975)
22 C/Sap	36.76	15.14	1.12	8.02	0.03	0.36	0.95	21.71	0.03	0.02		15.82	Taguchi and Watanabe (1973)
23 C/Sap	40.63	15.54	6.92	5.76	0.81	0.11	1.92	13.21	0.46	0.68	7.42	6.52	Seki <i>et al.</i> (1980)
24 C/Sap	37.16	14.98	12.01	4.11	0.34	0.13	1.80	14.79	0.27	0.88	8.41	5.12	Kimbara (1975)
25 C/SC	32.72	20.28	1.00		0.03	0.06	1.97	24.47	0.25	tr	7.02	12.57	Shimoda (1970)
26 C/M	48.58	13.44	17.85		1.78		2.71	13.14	0.88	1.61	8.00	6.96	Nichols (1970)
27 C/M	39.94	33.17	1.34	0.18	0.74		1.30	6.44	0.52	0.24	4.39	11.64	Sudo and Kodama (1957)
28 C/V	33.95	19.20	0.71	0.69	tr		0.70	26.31	0.74	0.05	6.55	11.26	Sugiura (1962)
29 C/V	34.00	16.25	12.60				0.50	22.16	0.37	0.28		13.95	Gallitelli (1959)
30 Al-C/M	47.4	20.7	8.9		0.97	0.08	1.3	6.0	0.33	0.95		9.79	Pacquet (1968)
31 Al-C/M	48.2	22.7	8.2		0.95	0.25	0.9	6.4	0.33	1.08		9.89	Pacquet (1968)
32 Al-C/M	49.1	22.9	5.72		0.64	0.21	1.07	7.87	0.26	0.96		10.6	Pacquet (1968)
33 Al-C/M	46.0	24.8	7.65		0.84	0.17	0.99	8.1	0.25	1.32		10.00	Pacquet (1968)
34 C/M	39.46	12.59	0.31	0.14	0.02		0.06	24.91	0.22	0.03	10.94	11.20	Takahashi (1959)
35 C/M	35.5	15.1	6.7	13.5	0.13	0.32	1.06	13.2	1.32	0.67		12.13	Almon <i>et al.</i> (1976)
36 C/M	37.2	15.5	6.70		0.4	0.01	1.0	18.9	0.2	1.4		18.4	Peterson (1961)
37 C/V	37.62	12.27	2.18					27.9			7.30	12.60	Melnik (1959)
38 C/Sap	34.25	11.63	4.21	3.91	0.20	0.12	1.39	29.26	0.26	0.04		14.73	Brigatti and Poppi (1984)
39 C/Sap	34.64	11.35	3.34	3.73	0.44	0.10	1.85	29.30	0.19	0.02		15.03	Brigatti and Poppi (1984)
40 C/Sap	38.43	16.31	3.62	5.33	0.36	0.12	0.28	22.77	0.48	1.20		11.10	Brigatti and Poppi (1984)

¹ C/Sap = chlorite/saponite; C/M = chlorite/montmorillonite; C/V = chlorite/vermiculite; C/SC = chlorite/swelling chlorite; Al-C/M = Al-chlorite/montmorillonite.

corrensite was present in amounts greater than 70% were selected. The chemical analyses and mineralogical designations as proposed by the referenced authors are listed in Table 1, wherein C/Sap = chlorite/saponite, C/M = chlorite/montmorillonite, C/V = chlorite/ver-

miculite, C/SC = chlorite/swelling chlorite, and Al-C/M = Al-chlorite/montmorillonite.

Assuming the minerals to be interstratifications of chlorite and some type of smectite, the formulae were recalculated by: (1) balancing the charges on the basis

Table 2. Unit-cell *b* dimensions of selected corrensites.

Sample ¹	<i>b</i> (Å)	Sample ¹	<i>b</i> (Å)	Sample ¹	<i>b</i> (Å)
1 (C/Sap)	9.222	4 (C/Sap)	9.215	6 (C/Sap)	9.215
7 (C/M)	9.252	10 (C/V)	9.240	13 (C/Sap)	9.228
14 (C/Sap)	9.252	15 (C/Sap)	9.252	16 (C/Sap)	9.258
18 (C/Sap)	9.258	20 (C/Sap)	9.258	21 (C/Sap)	9.216
36 (C/M)	9.240	38 (C/Sap)	9.240	39 (C/Sap)	9.234
40 (C/Sap)	9.228				

¹ Source and symbolism listed in Table 1.

of 50 negative charges (O₂₀(OH)₁₀); (2) assigning all of the Si to tetrahedral coordination together with enough Al to bring the total to 8; (3) assigning Ca, Na, and K to interlayer positions of the swelling component; (4) assigning all the residual cations to octahedral coor-

dinations. The recalculated chemical formulae are listed in Table 3.

Correlation tests were performed by means of a BMD02R stepwise multiple-regression program. The variability of chemical properties was studied by

Table 3. Recalculated chemical formulae of selected corrensites.

Sample ¹	IV		VI						Exchange				Charge unbalance			
	Si	Al	Al	Mg	Fe ³⁺	Fe ²⁺	Mn	Ti	Σ	Na	K	Ca/2	Total	IV	VI	Total
1 C/Sap	6.24	1.76	1.03	6.48	0.28	0.99		0.03	8.81	0.13	0.02	0.64	0.79	-1.76	+0.99	-0.77
2 C/Sap	5.95	2.05	0.70	5.73	1.59	0.71			8.73	0.20		0.10	0.30	-2.05	+1.75	-0.30
3 C/Sap	5.22	2.78	2.12	6.74	0.02	0.34	0.02		9.24	0.10	0.02	0.06	0.18	-2.78	+2.62	-0.16
4 C/Sap	5.54	2.46	1.21	8.15	0.03	0.15	0.01		9.55	0.04	0.03	0.06	0.13	-2.46	+2.34	-0.12
5 C/Sap	5.78	2.22	2.20	6.02	0.09	0.16	0.03		8.50		0.07	0.86	0.93	-2.22	+1.29	-0.93
6 C/Sap	5.95	2.05	1.00	8.31	0.02	0.09	0.01		9.43	0.04	0.05	0.12	0.21	-2.05	+1.88	-0.17
7 C/M	7.03	0.97	2.22	4.29	0.78		0.01	0.09	7.39	0.17	0.57	0.32	1.06	-0.97	-0.04	-1.01
8 C/V	5.77	2.23	1.29	6.01	0.37	1.27		0.06	9.00	0.20	0.04	0.22	0.46	-2.23	+1.78	-0.45
9 C/V	6.24	1.76	0.88	3.10	2.62	1.30			7.90	0.21		0.26	0.47	-1.76	+1.30	-0.46
10 C/V	7.33	0.67	1.87	5.83	0.23	0.05		0.02	7.99	0.03	0.05	0.52	0.60	-0.67	+0.10	-0.57
11 C/M	6.37	1.63	1.40	4.81	1.02	0.94	0.03		8.20	0.09	0.10	0.64	0.83	-1.63	+0.82	-0.81
12 C/Sap	6.24	1.76	1.39	6.24	0.23	0.58	0.03		8.47	0.06		1.14	1.20	-1.76	+0.56	-1.20
13 C/Sap	6.61	1.39	0.54	5.83	1.44	0.35		0.02	8.18	0.14	0.05	0.83	1.03	-1.39	+0.38	-1.01
14 C/Sap	6.24	1.76	1.13	4.80	0.94	1.06	0.02	0.01	7.96	0.41	0.03	1.30	1.74	-1.76	+0.01	-1.75
15 C/Sap	6.14	1.86	1.04	4.38	1.52	0.61	0.03	0.08	7.66	0.49	0.07	1.28	1.84	-1.86	+0.04	-1.82
16 C/Sap	6.37	1.63	1.56	3.94	0.90	1.37	0.06	0.04	7.87	0.39	0.26	0.72	1.37	-1.63	+0.28	-1.35
17 C/V	5.81	2.19	1.37	5.36	1.41	0.17			8.31	0.23	0.15	0.40	0.78	-2.19	+1.40	-0.79
18 C/Sap	6.25	1.75	1.24	3.59	1.17	1.76	0.04	0.08	7.88	0.36	0.19	0.88	1.43	-1.75	+0.33	-1.42
19 C/Sap	5.89	2.11	1.07	3.18	2.28	0.68	0.04	0.11	7.36	0.59	0.15	1.08	1.82	-2.11	+0.29	-1.82
20 C/Sap	6.22	1.78	1.10	4.88	0.94	1.05	0.02	0.01	8.00	0.40	0.03	1.30	1.73	-1.78	+0.06	-1.72
21 C/Sap	6.47	1.53	2.01	5.84	0.23	0.20	0.01	0.05	8.34	0.19	0.02	0.30	0.51	-1.53	+1.01	-0.51
22 C/Sap	6.47	1.53	1.61	5.70	0.15	1.18	0.06		8.70	0.01	0.01	0.36	0.38	-1.53	+1.16	-0.37
23 C/Sap	6.99	1.01	2.14	3.39	0.90	0.83	0.02	0.11	7.39	0.15	0.15	0.68	0.98	-1.01	+0.04	-0.97
24 C/Sap	6.49	1.51	1.57	3.85	1.58	0.60	0.02	0.04	7.66	0.09	0.20	0.68	0.97	-1.51	+0.55	-0.96
25 C/SC	5.79	2.21	2.02	6.45	0.13	0.01			8.61	0.09		0.74	0.83	-2.21	+1.37	-0.84
26 C/M	7.22	0.78	1.58	2.91	2.00			0.20	6.69	0.25	0.31	0.86	1.42	-0.78	-0.64	-1.42
27 C/M	6.53	1.47	4.92	1.57	0.17	0.03		0.09	6.78	0.17	0.05	0.46	0.68	-1.47	+0.83	-0.64
28 C/V	5.90	2.10	1.83	6.81	0.09	0.10			8.83	0.25	0.01	0.26	0.52	-2.10	+1.58	-0.52
29 C/V	5.86	2.14	1.16	5.70	1.64				8.50	0.12	0.06	0.18	0.36	-2.14	+1.80	-0.34
30 Al-C/M	7.68	0.32	3.64	1.45	1.09		0.01	0.12	6.31	0.10	0.20	0.44	0.74	-0.32	-0.41	-0.73
31 Al-C/M	7.58	0.42	3.79	1.50	0.97		0.03	0.11	6.40	0.10	0.22	0.30	0.62	-0.42	-0.22	-0.64
32 Al-C/M	7.67	0.33	3.89	1.83	0.67		0.03	0.08	6.50	0.08	0.19	0.36	0.63	-0.33	-0.28	-0.61
33 Al-C/M	7.18	0.82	3.75	1.89	0.90		0.02	0.10	6.66	0.08	0.26	0.32	0.66	-0.82	+0.17	-0.65
34 C/M	7.09	0.91	1.76	6.68	0.04	0.02			8.50	0.08	0.01	0.02	0.11	-0.91	+0.80	-0.11
35 C/M	6.36	1.64	1.55	3.53	0.90	2.02	0.05	0.02	8.07	0.46	0.15	0.42	1.03	-1.64	+0.63	-1.01
36 C/M	6.63	1.37	1.89	5.02	0.90			0.05	7.87	0.07	0.32	0.38	0.73	-1.37	+0.65	-0.72
37 C/V	6.67	1.33	1.24	7.38	0.29				8.91					-1.33	+1.35	+0.02
38 C/Sap	5.99	2.01	0.39	7.63	0.56	0.57	0.02	0.03	9.20	0.09	0.01	0.52	0.62	-2.01	+1.41	-0.60
39 C/Sap	6.06	1.94	0.40	7.65	0.44	0.55	0.02	0.06	9.12	0.06	0.01	0.68	0.75	-1.94	+1.20	-0.74
40 C/Sap	6.39	1.61	1.59	5.65	0.45	0.74	0.02	0.04	8.51	0.16	0.25	0.10	0.51	-1.61	+1.10	-0.51

¹ See footnote 1 and references listed in Table 1.

Q-MODE multivariate analysis following the basic principles found in Klovan and Imbrie (1971) and Davis (1973). The purpose of this analysis was to ascertain the similarities among several samples on the basis of prefixed variables (chemical data in this study). At first, all variables were reduced to a percentage of their range of variability and so normalized. An $n \cdot n$ correlation matrix (n = number of samples) was created, and from this a prefixed number p ($p < v$) (where v is the number of variables) of eigenvalues and eigenvectors was extracted (principal factor score matrix). A p -dimensional space was so created where the coordinates of the samples were obtained by multiplying the elements of the eigenvectors matrix by the values of the corresponding variables (principal factor loadings). Three p factors (F.1, F.2, F.3) were rotated in p -dimensional space where the variance of the sample loadings was maximized (varimax factor score matrix). The coordinates of the samples in this new space were obtained as described above by multiplying the elements of the varimax-factor score matrix by the values of the corresponding variables. The sum of the square of these coordinates (communality) provided an index of the reliability of this set of data to explain the variance of the samples. To visualize the results, the coordinates so obtained were normalized and plotted in triangular diagrams whose apexes represent the three factors (F.1, F.2, F.3).

The computer program was used to distinguish different corrensite-type minerals from a chemical point of view. In analysis (1), all proposed definitions (as in Table 1) were considered. In analysis (2), the samples were redefined as low-charge corrensite (C/Sap and C/M) and high-charge corrensite (C/V and C/SC); the Al-C/M was not considered. In analysis (3) all of the samples (except Al-C/M) were compared to saponite and vermiculite (the chemical formulae of saponite and vermiculite were derived from literature analyses reported by Brigatti (1982) and Brigatti and Poppi (1980) and recalculated as previously described for corrensite). In analysis (4) all of the data in analysis (3) were compared to trioctahedral chlorites whose chemical formulae were also recalculated as corrensite from the chemical analyses in Foster (1962). In all analyses, data not sufficiently detailed (communality < 0.98) were not considered. The meaning of the vertices (F.1, F.2, F.3) in the triangular diagrams (Figure 1) can be deduced from the varimax factor score matrix relative to each one of them (Table 4).

RESULTS

The correlation matrix between b -dimensions and chemical properties of corrensite is given in Table 5. The b -dimension seems to correlate principally with the charge unbalance and the amount of octahedral Mg, but the low variation of the b -dimension and high

Table 4. Varimax factor-score matrices.

Coordination	Analysis (1)			Analysis (2)			Analysis (3)			Analysis (4)			
	F.1	F.2	F.3	F.1	F.2	F.3	F.1	F.2	F.3	F.1	F.2	F.3	
IV	Al	0.336	-0.133	0.310	0.385	0.303	-0.218	0.023	0.309	-0.642	0.187	0.420	0.296
	Fe	0.009	0.491	-0.063	0.017	0.015	0.329	0.053	-0.009	0.011	-0.142	-0.068	0.319
	Al	0.483	-0.062	0.087	0.441	0.024	0.124	-0.030	0.279	-0.138	0.264	0.379	-0.319
	Mg	-0.110	0.171	0.369	-0.088	0.394	0.093	0.930	0.031	-0.150	0.805	-0.070	0.365
	Fe ³⁺	-0.001	-0.117	0.410	0.044	0.413	-0.175	-0.279	0.107	-0.601	0.248	0.489	-0.314
	Fe ²⁺	0.483	-0.091	0.145	0.489	0.067	-0.035	-0.044	0.426	0.093	-0.184	0.343	0.150
	Mn	-0.090	0.043	0.446	-0.080	0.446	0.036	0.043	0.710	0.393	-0.351	0.457	0.261
	Ti	-0.105	0.326	0.096	-0.156	0.101	0.384	-0.113	0.327	0.026	-0.083	0.315	-0.056
	Σ	-0.082	0.069	0.555	-0.050	0.564	0.013						
Exchange	Na	0.032	0.657	0.096	-0.026	0.142	0.705						
	K	0.421	-0.031	0.023	0.441	0.029	-0.046						
	Ca	0.452	0.373	-0.202	0.424	-0.173	0.375						
Charge unbalance	IV	41.916	23.179	27.355	43.685	29.431	18.661	0.192	0.146	-0.146	-0.044	0.072	0.619
	VI							38.016	20.879	32.209	39.996	20.623	29.694
Total	Variance												

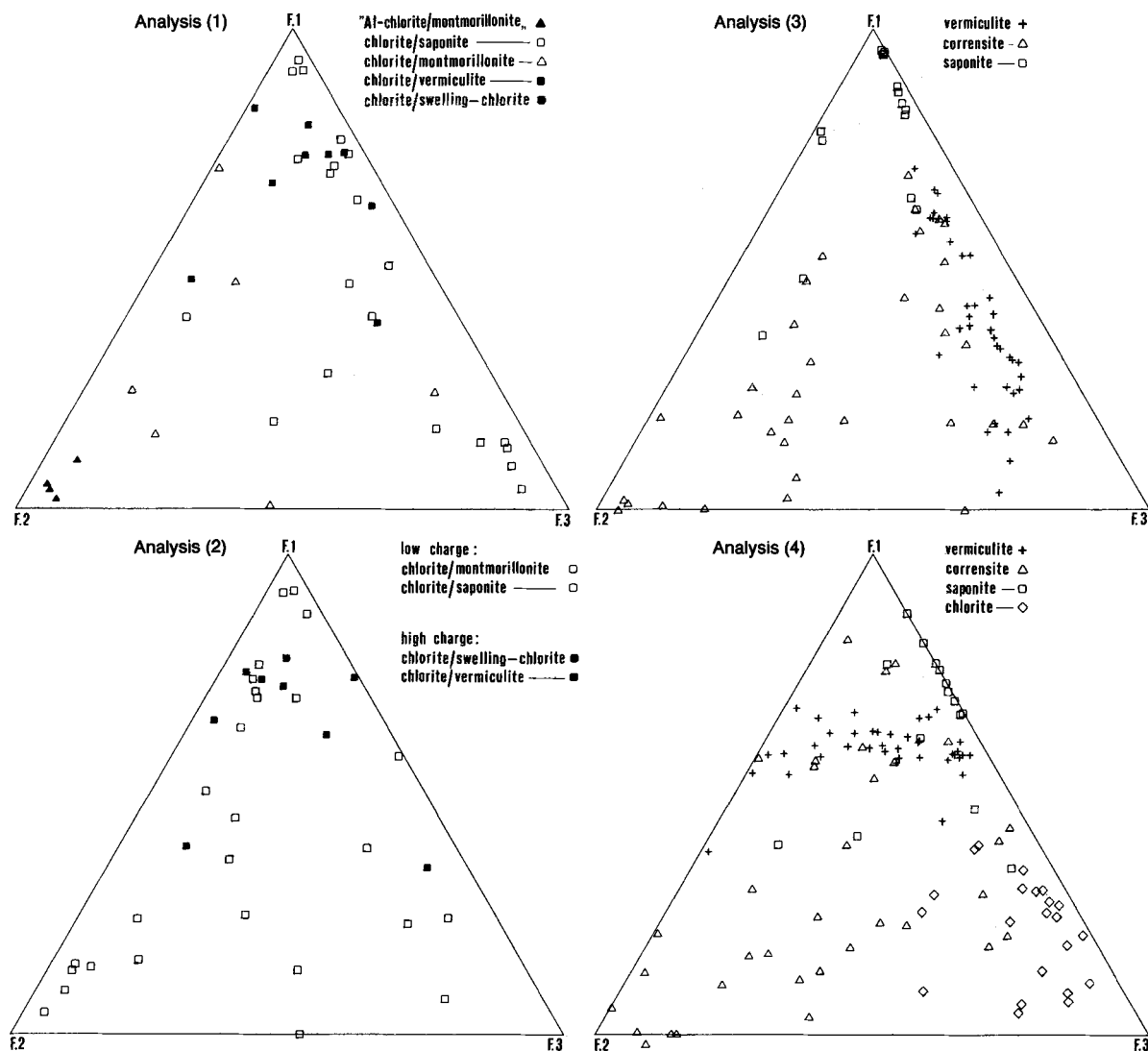


Figure 1. Q-MODE multivariate analysis of selected corrensites, chlorites, saponites, and vermiculites.

variation of the chemical composition did not allow a reliable hypothesis on this correlation to be put forward.

The results of the Q-MODE multivariate analysis can be summarized as follows (Figure 1):

Analysis (1). The factors F.1, F.2, F.3 are affected principally by octahedral populations. The Al-C/M materials are distinct, but their chlorite components are probably dioctahedral; the C/V materials plot towards the F.1 apex; the C/Sap materials are scattered and not

Table 5. Correlation matrix between the *b* dimension and chemical properties of selected corrensites.

Variance	1	2	3	4	5	6	7
1	1.000	-0.786	0.627	-0.565	-0.782	-0.296	0.884
2		1.000	-0.861	0.798	0.984	0.394	-0.769
3			1.000	-0.965	-0.914	-0.640	0.584
4				1.000	0.863	0.643	-0.518
5					1.000	0.524	-0.770
6						1.000	-0.149
7							1.000

1 = *b* (Å); 2 = Mg(VI)/Σ(VI); 3 = (Al + Fe³⁺)(VI)/Σ(VI); 4 = (Mg + Fe²⁺)(VI)/Σ(VI); 5 = Mg(VI); 6 = Si(IV)/Al(IV); 7 = Charge imbalance.

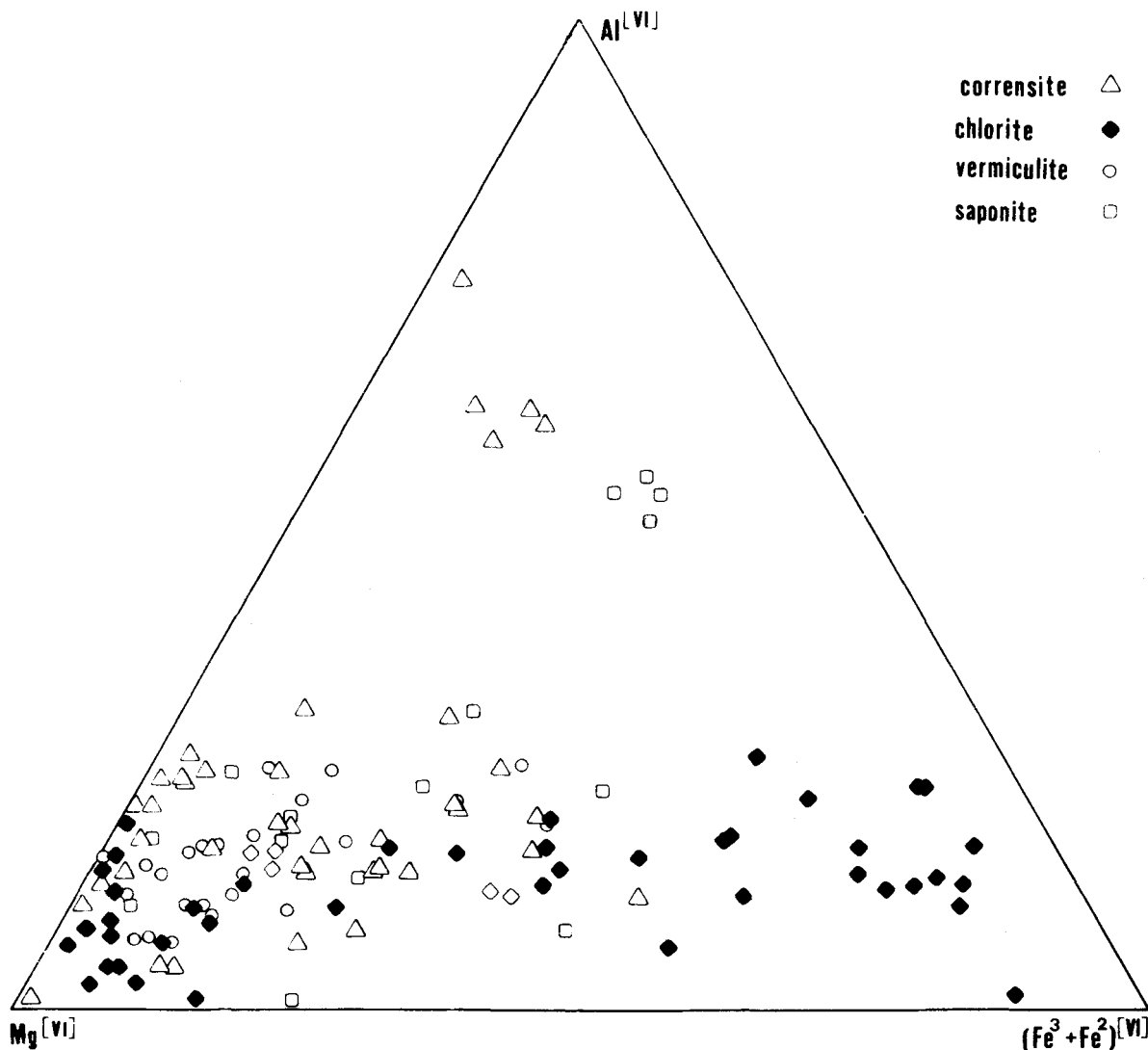


Figure 2. Relation between Mg(VI), Al(VI), $(Fe_{tot})(VI)$ in selected corrensites, chlorites, saponites, and vermiculites.

distinct from the C/M materials. Apparently F.1 (principally affected by Mg in octahedral coordination) discriminates the C/V materials even if some C/Sap materials fall into the C/V area.

Analysis (2). A high Mg content in octahedral coordination seems to characterize high-charge corrensites, but some low-charge corrensites also plot in this area. Low-charge corrensites fall into a very large area compared with that of high-charge corrensite because of the larger compositional range of the low-charge materials.

Analysis (3). The vermiculites, saponites, and corrensites plot in three distinct areas. The broader compositional range of corrensites (in particular Al in the octahedral sheet) and the differentiation of the three

groups on the basis of their chemistry can be deduced from the diagram.

Analysis (4). On the basis of F.1 (principally affected by octahedral Mg content), saponite and vermiculite can be distinguished from chlorite and corrensite, whereas, F.2 (principally affected by Fe in the octahedral sheet) distinguishes corrensites from chlorites. Corrensite has a larger compositional area than chlorite.

DISCUSSION AND CONCLUSIONS

The distinction between vermiculite and saponite has generally been made on the basis of layer charge that is clearly correlated with the composition of 2:1 silicate layer. The experimental tests to determine the

layer charge of smectites are relatively standardized (Brindley and Brown, 1980), and thus chemical treatments to distinguish vermiculite from saponite are commonly used to characterize the swelling layer component of corrensite and, thus, to describe the corrensite itself. The compositional variability of corrensite is due to the compositional range of both the swelling and the nonswelling component; the chemical variability is higher in the chlorite layers than in the swelling layers. The data used to evaluate the swelling layer charge are, thus, not reliable for corrensites because of the large proportion of the chlorite component in the total composition.

Compositional transitions between chlorite, corrensite, and trioctahedral smectites (such as saponite or vermiculite) are also evident. The continuous chemical variation of corrensite between trioctahedral chlorite and saponite or vermiculite can be hypothesized on the basis of Mg and Fe mobilization, probably due to hydrothermal solutions, as is shown in analysis (4) of Figure 1. In particular, Fe appears to play an important role in the chlorite-smectite transition, as is shown also in Figure 2. In this triangular diagram, saponite, vermiculite, corrensite, and chlorite are plotted in terms of their octahedral population ($\text{Al-Mg-Fe}_{\text{tot}}$). It can be seen that Al always constitutes less than 30% of the octahedral populations, whereas a continuous range between Fe and Mg is shown. Where $\text{Fe}/(\text{Fe} + \text{Mg}) > 50\%$, only chlorite is present: with an increase in Mg, chlorite seems to transform into interlayer minerals (such as corrensite) and finally (probably because of iron oxidation, as is shown in analysis (4) of Figure 1) into trioctahedral smectites, such as saponite and vermiculite.

The statistical analysis shows that although chemically corrensites can be distinguished from saponites, vermiculites, and chlorites, distinct compositional fields for the various types of mixed-layer chlorite/swelling layer minerals cannot be drawn. Thus, corrensite must be described chemically as a mineralogical species characterized by an interstratification of a trioctahedral chloritic component and an ill-defined trioctahedral swelling component, as suggested by Bailey *et al.* (1982) from a structural point of view.

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Резюме—Статистические анализы литературных химических данных по коррензитовым минералам вызывают большую композиционную разнообразность, которая более очевидна в октаэдрической, чем тетраэдрической координации. Mg занимает 40–80% октаэдрических мест, тогда как остальные места заполняются Al и Fe²⁺. Приблизительно 15–30% тетраэдрических мест заполнено Al. Несмотря на композиционную разнообразность нет очевидных четких областей для нескольких типов смешанно-слоистого триоктаэдрического хлорита/триоктаэдрического набухающего слоя. Сравнение статистических анализов композиции коррензита с сапонитом, вермикулитом и хлоритом наводит на мысль, что коррензит является промежуточным соединением между триоктаэдрическим хлоритом и триоктаэдрическим смектитом. Если Fe/(Fe + Mg) > 50%, только хлорит является предпочтительным, но с увеличением Mg хлорит, преобразовывается в коррензит и при последующем окислении железа — в триоктаэдрический смектит. Несмотря на химическое различие между коррензитом, хлоритом и сапонитом, коррензиты, по видимому, являются химически хорошо-определенными видами. С другой стороны, коррензиты не могут быть химически схарактеризованы на основе их набухающего компонента. Таким образом, современное определение коррензита как регулярной прослойки 1:1 триоктаэдрического хлорита и триоктаэдрического смектита или вермикулита является соответствующим. [E.G.]

Resümee—Statistische Analysen von chemischen Daten aus der Literatur über Corrensitminerale deuten auf eine große Variabilität der Zusammensetzung hin, die in der oktaedrischen Koordination ausgeprägter ist als in der tetraedrischen Koordination. Mg besetzt 40–80% der oktaedrischen Plätze, während Al und Fe den Rest besetzen. Ungefähr 15–30% der Tetraederplätze werden von Al besetzt. Trotz dieser chemischen Variabilität sind keine getrennten Bereiche für die verschiedenen Arten von Wechsellagerung aus trioktaedrischem Chlorit und trioktaedrischer quellfähiger Schicht zu erkennen. Statistische Analysen der Corrensitzusammensetzung im Vergleich zu Saponit, Vermiculit und Chlorit deuten darauf hin, daß der Corrensit ein Zwischenglied zwischen trioktaedrischem Chlorit und trioktaedrischem Smektit ist. Wenn das Verhältnis Fe/(Fe + Mg) > 50% ist, wird Chlorit allein bevorzugt, aber mit zunehmendem Mg-Gehaltschein Chlorit in Corrensit umgewandelt zu werden und dann durch Oxidation von Fe in trioktaedrischen Smektit. Trotz der chemischen Variabilität zwischen Corrensit, Chlorit und Saponit scheint der Corrensit eine gut definierte Phase zu sein. Auf der anderen Seite kann der Corrensit chemisch nicht aufgrund seiner quellfähigen Komponente charakterisiert werden. Daher ist die gegenwärtige Definition von Corrensit als eine regelmäßige 1:1 Wechsellagerung von trioktaedrischem Chlorit und entweder trioktaedrischem Smektit oder Vermiculit zutreffend. [U.W.]

Résumé—Des analyses statistiques de données chimiques de la littérature concernant les minéraux corrensites suggèrent une variabilité de composition très grande, plus évidente dans la coordination octaédrale que tétraédrale. Mg occupe 40–80% des sites octaédraux, avec Al et Fe^{2+} remplissant le reste. Approximativement 15–30% des sites tétraédraux sont remplis par Al. Malgré cette variabilité de composition, il n'y a pas d'apparence de champs distincts pour les différents types de couches mélangées chlorite trioctaédrale/couche gonflante trioctaédrale. Des analyses statistiques de la composition de corrensite comparée à la saponite, la vermiculite et la chlorite suggèrent que la corrensite est un intermédiaire entre la chlorite trioctaédrale et la smectite trioctaédrale. Si $Fe/(Fe + Mg) > 50\%$, la chlorite seule est favorisée, mais avec l'augmentation de Mg, la chlorite semble se transformer en corrensite et ensuite, par oxydation de fer, en smectite trioctaédrale. Malgré la variabilité chimique entre la corrensite, la chlorite et la saponite, la corrensite semble être chimiquement une espèce bien définie. Mais d'autre part, la corrensite ne peut pas être caractérisée chimiquement sur la base de son composé gonflant. Ainsi, la définition actuelle de la corrensite en tant qu'interstratification 1:1 de chlorite trioctaédrale et soit de la smectite ou de la vermiculite est appropriée. [D.J.]