Chromiferous chamosite from Pokphur magnetite body, Nagaland, India

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Magnetite ore from Pokphur region, Nagaland, invariably contains a silicate phase which is identified as chamosite. Chromium and nickel values in the ore are found to be mainly contributed by chamosite. Detailed mineragraphy and mineral chemistry of chamosite indicate in favour of its primary origin.

DURING the course of an investigation for recovery of nickel from magnetite ore body of the Pokphur region (25°56'45":94°05'), Nagaland, the presence of nickel-bearing chamosite, essentially as a rock-forming mineral, was noted. The mineral is also enriched in chromium. This note describes briefly the distinctive properties of chamosite and discusses its genesis.

Studies of magnetite samples under transmitted-light microscope indicate the ubiquitous presence of densely packed aphanitic crystallites. XRD studies (Phillips PW-1700) reveals this phase to be chamosite (iron chlorite). Its diagnostic peaks are at 7.05 Å (100), 3.54 Å (50), 4.69 Å (30), 2.52 Å (20), 1.56 Å (20), which match well with the data given in the JCPDS data book[1]. Other reflection peaks are those of the associated magnetite (2.53 Å), hematite (2.69 Å) and chromite minerals (Figure 1). In addition, plagioclase feldspar and quartz, occurring in minor amounts, are recognized under the optical microscope. Examination of the mineral under a scanning electron microscope reveals a mass of randomly arranged minute crystallites.

X-ray wavelength dispersive spectroscopic (WDS) study coupled with SEM (JEOL, JSM 35CF model) on a selectively scooped powder sample shows that the crystallites contain Fe, Al and Si as major constituents, confirming the phase to be chamosite (Figure 2). The other phases recorded are Cr and Mg, with minor amount of Ni and Mn (Figure 2). The electron probe microanalyses (EPMA) results (using a CAMECA probe) of the chamosite phase (7 specimens) are listed in Table 1 together with the results of analysis of chamosite from Corby, Northamptonshire[2], and Quintin, France[3], and Arakawa, Japan[3]. The data show that the Pokphur chamosite is notably enriched in Cr (Cr_2O_3 2.60–4.70%). The chamosite is high in Fe^{2+} and Al content and appears in association with chromite. This is in contrast to the data of Albee[4], who records that chlorite having appreciable Cr_2O_3 and association with chromite are usually low in both Al and Fe. The range of NiO present in chamosite varies between 0.40 and 0.70%. Both Ni and Mn (average MnO 0.25) appear as minor substituents of iron.

The name chamosite was first given to a specimen having 14 Å chlorite structure[5]. Brindley[6] described the chamosite to have two kinds of stacking kaolinite-type layer structure. Nelson and Roy[7] grouped only 7 Å chamosite under septechlorite as they are related chemically to chlorite and structurally to serpentine. The 7 Å chamosite of Pokphur, thus, belongs to the septechlorite family. Brown and Bailey[3] gave the formula for the mineral as (Fe, Al, Mg)$_6$ (Fe, Al)$_4$O$_{10}$(OH)$_8$. It was also reported[3] that the formula can

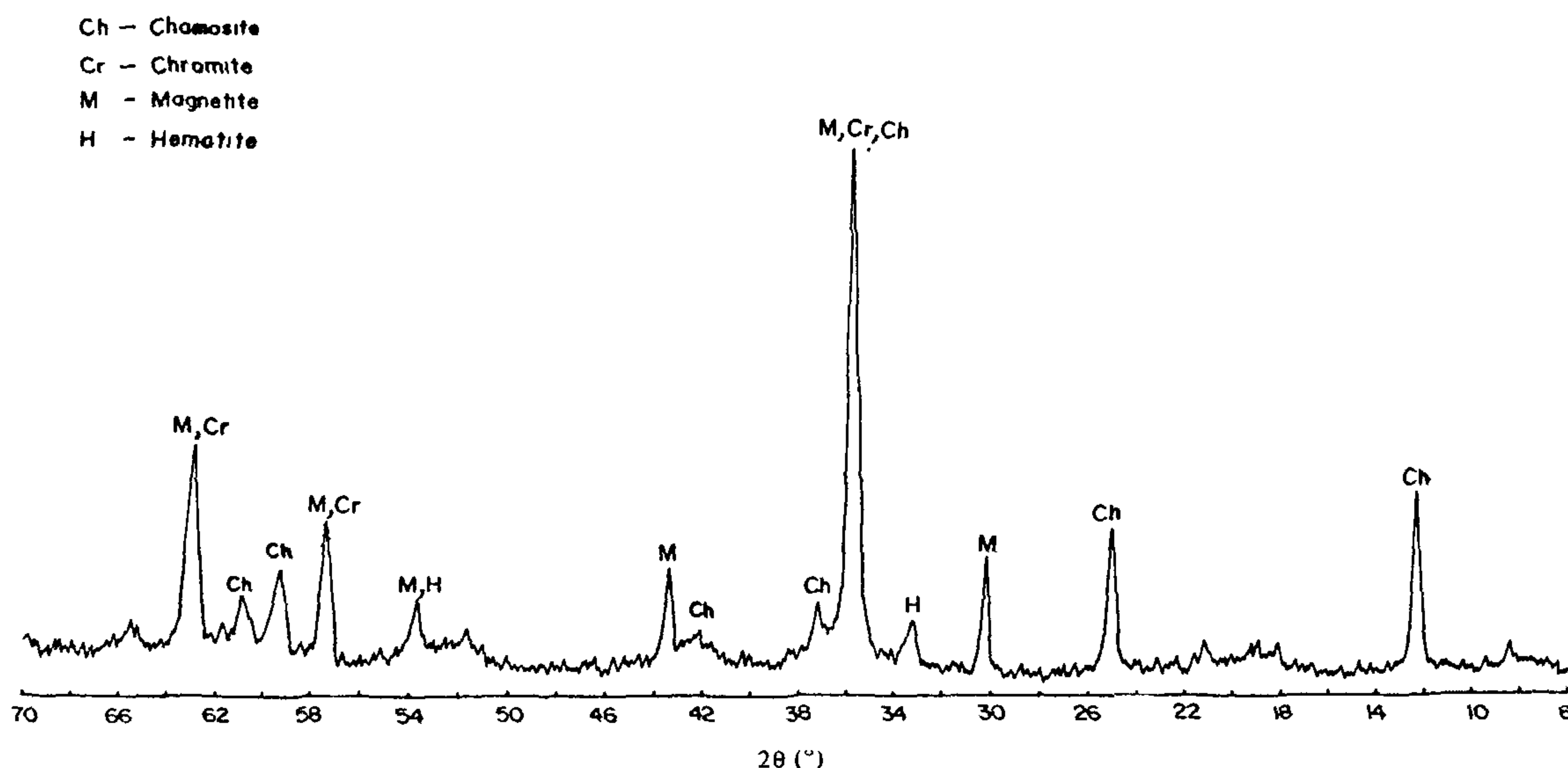Ch — Chamosite
Cr — Chromite
M — Magnetite
H — Hematite

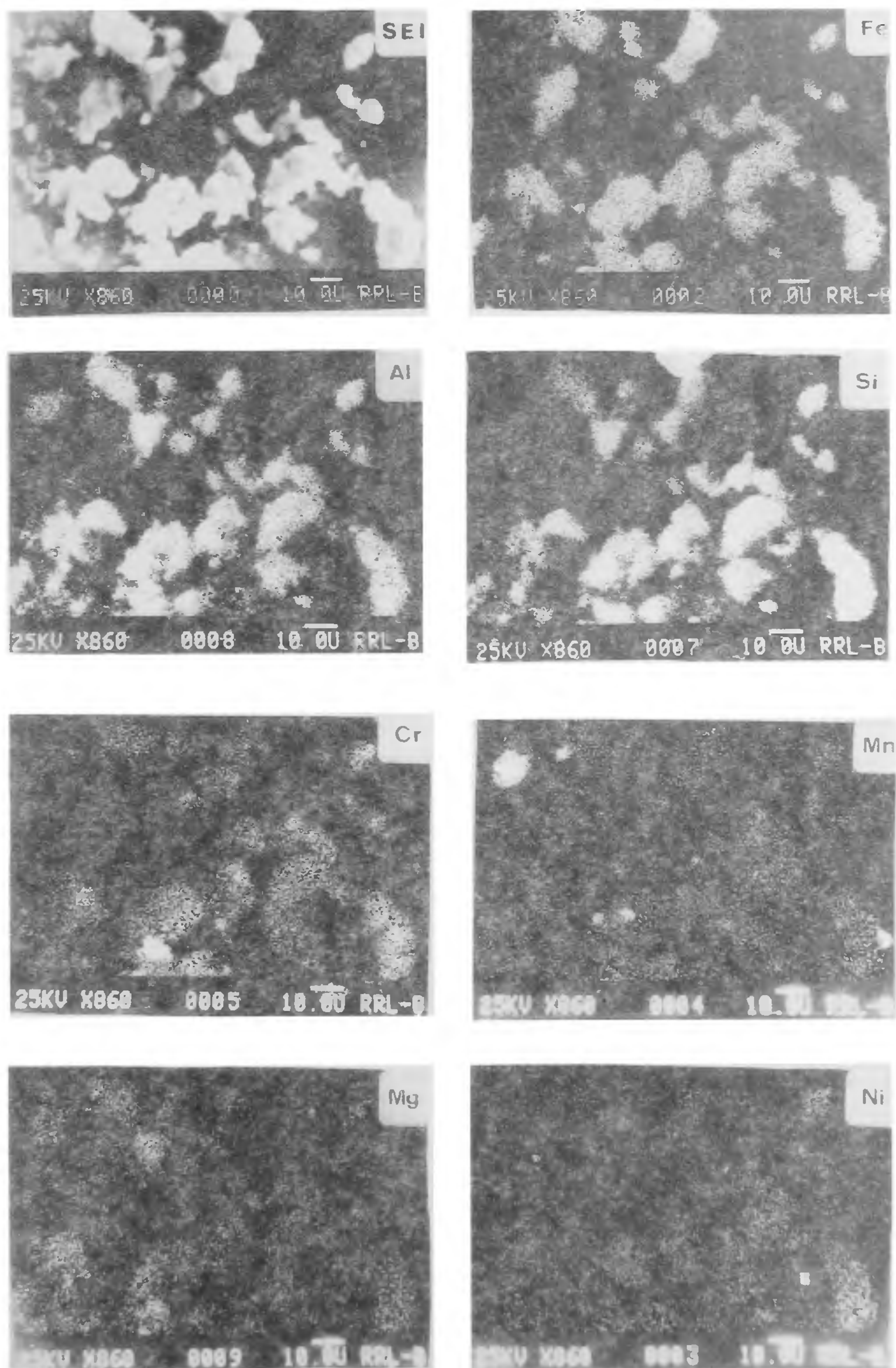Figure 1. XRD pattern of Pokphur chamosite sample

Figure 2. Scanning electron micrographs of chamosite crystallites showing secondary electron image (SEI) and X-ray image map of Fe, Al, Si, Cr, Mn, Mg, Ni elements.

Table 1. Chemical composition of chamosite

Elements	Percentages (%)									
	1	2	3	4	5	6	7	8	9	10
SiO_2	21 93	23 13	21.54	22 42	20 84	20 31	22 27	24 50	23 81	22 27
TiO_2	0 09	0 04	0 01	0 07	0 06	0 03	0 02	–	–	0 08
Al_2O_3	17 88	20 63	21 62	20 06	18 91	19 00	20 28	16 30	23 12	21 40
FeO^t	44 02	44 85	45 16	45 33	44 19	44 79	44 80	38 91	39 68	43 08
MnO	0 29	0 30	0 33	0 47	0 19	0 25	0 27	3 33	–	0 05
MgO	1 10	1 53	1 27	1 40	1 33	1 15	1 36	4 59	2 72	2 35
CaO	0 09	0 03	0 07	0 09	0 01	0 02	0 07	–	–	–
Na_2O	0 12	–	0 11	–	0 14	0 01	–	–	–	0 35
K_2O	0 04	0 06	0 03	0 03	0 07	0 03	0 02	–	–	–
Cr_2O_3	4 71	2 59	2 91	3 45	3 02	2 90	2 94	–	–	–
NiO	0 41	0 64	0 68	0 53	0 51	0 41	0 72	–	–	–
H_2O								10 10	10 67	11.36
Total	**90.66**	**93.78**	**93.53**	**93.94**	**89.27**	**88.96**	**93.20**			

	Formula on the basis of 9(O, OH)									
Si	1 303	1.416	1 318	1 387	1 217	1 184	1 381	1 394	1 327	
Al	0 697	0.584	0 682	0 613	0.783	0 816	0 619	0 606	0 673	
Al	0 552	0 902	0.88	0 844	0 513	0 49	0 835	0 49	0 847	
Fe^{2+}	2 188	2 295	2 313	2 347	2 163	2.187	2 277	1 854	1.848	
Mn^{2+}	0 014	0 015	0.015	0.022	0 10	0 01	0.014	0 161	–	
Mg	0 096	0.139	0 114	0 13	0 116	0 098	0 139	0 39	0 225	
Ca	0 007	–	0 004	0 007	–	–	0 003	–	–	
Na	0 014	–	0 014	–	0 014	–	–	–	–	
K	–	–	–	–	–	–	–	–	–	
Cr	0 221	0 125	0 14	0 17	0 133	0 133	0 138	–	–	
Ni	0 018	0 029	0 033	0 026	0 021	0 017	0 033	–	–	
H	3 698	2 54	2 644	2.50	4 186	4 304	2.756	4 318	3 968	

1–7: EPMA, 8–10 wt chemical, 1–7 H_2O by difference, 1–7. Pokphur, India,
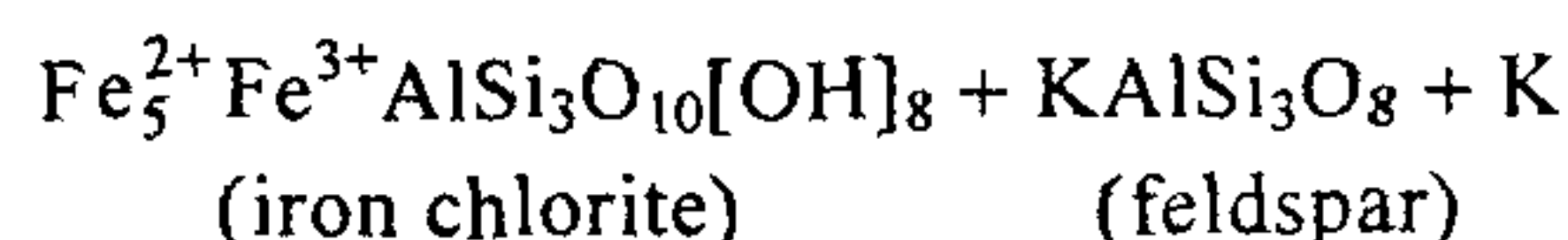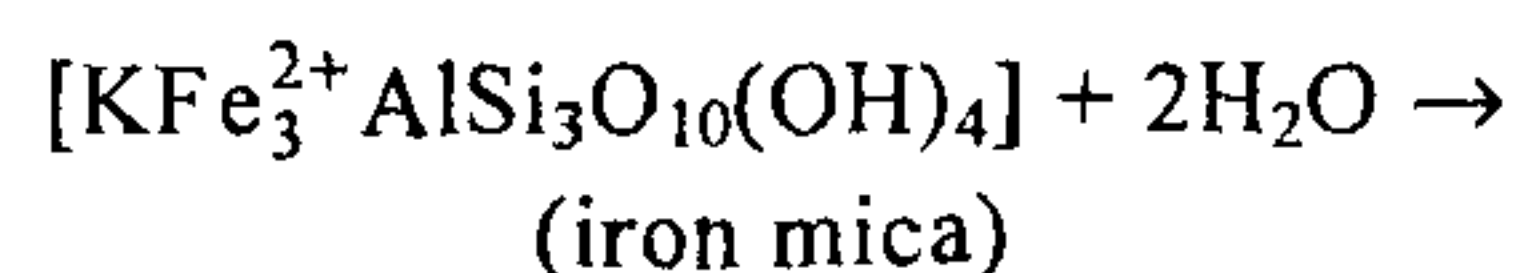8· Quintin, France (ref 3), 9 Corby, Northamptonshire (ref 2), 10: Arakawa, Japan (ref. 3), 'Total

be modified as $(Fe, Al, Mg, Mn)(Si, Al)_4O_{10}(OH)_8$ for those minerals containing manganese. The present authors suggest the general formula of Pokphur chamosite to be $(Mn_{0.01}, Ni_{0.02})(Cr_{0.15}, Mg_{0.12})(Fe^{2+}_{2.25} Al_{1.40} Si_{1.31})O_9 (H_2O)_{3.23}$ on the basis of 9(O, OH).

The Cr- and Fe^{2+}-containing clinochlore from Kaukapa, Kape, New Zealand, has been designated as 'chromiferous' clinochlore[8]. The term 'chromium' chlorite has been used by Lapham[9] for those chlorites where chromium substitution is between 0–8% Cr_2O_3. Based on Cr substitution either in tetrahedral or octahedral site, the term kochubeite and kammererite, respectively, was used[9]. Since the structural details of Pokphur chamosite are not established, the authors suggest to use the prefix 'chromiferous' following previous researchers. The chromiferous chamosite from pokphur is distinguished from kammererite by its high Fe:Mg ratio.

Unlike other chlorites, chamosite of the Pokphur region does not appear as product of hydrothermal alteration. Chayes[10] suggested that iron chlorite may result from the transformation of iron mica and may be expressed as

$$[KFe^{2+}_3 AlSi_3O_{10}(OH)_4] + 2H_2O \rightarrow$$
$$\text{(iron mica)}$$

$$Fe^{2+}_5 Fe^{3+} AlSi_3O_{10}[OH]_8 + KAlSi_3O_8 + K$$
$$\text{(iron chlorite)} \qquad \text{(feldspar)}$$

Formation of Pokphur chamosite through such a process does not seem feasible as the rock is almost devoid of potassium. It is different from authigenic chamosite that occurs as a grain coating in sandstone[11]. Taylor[12] reported the chamosite in Northampton iron formation to have formed as chemical precipitates and not as a replacement mineral. The chlorite associated with unaltered albite and pyroxene from spilites of northern New Zealand is observed by Battey[13] to have crystallized as a primary mineral from a residual liquid rich in iron. The authors support Taylor[12] and Battey[13] and consider this chamosite to be a primary mineral in the volcanogenic magnetite body of Pokphur. The large volume of magnetite associated with chamosite attests to the iron enrichment in the residual liquid. The close association of unaltered plagioclase feldspar, the lack of a distinct ferromagnesian phase and the presence of chromium and nickel within chamosite are supportive

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evidences in favour of its primary origin. The overall greenish-black colour of the rock is due to subsequent oxidation of chromiferous chamosite.

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10 Chayes, F., *J Geol* , 1955, **63**, 75.
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Cryptic genes: Are directed mutations always beneficial?

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While the debate on the existence of 'directed', 'Cairnsian', 'adaptive' or 'post-selection' mutations still continues, the suggestion that such a feature will be strongly advantageous seems to be uncritically accepted. We modelled competition in a chemostat with the substrate alternating between a 'normal' and an 'alternative' nutrient. Simulations involving genotypes (1) with inducible operon for alternative substrate, (2) without any gene for the alternative substrate, (3) with a cryptic gene for the alternative substrate and the ability to bring about a directed mutation and (4) with a cryptic gene having mutational hotspot showed that a directed mutation conferred little selective advantage. The widely held belief is thus challenged and we need to look into the directed-mutation controversy with a new insight.

CRYPTIC genes are known to occur widely in bacteria. These genes are normally silent but specific mutations
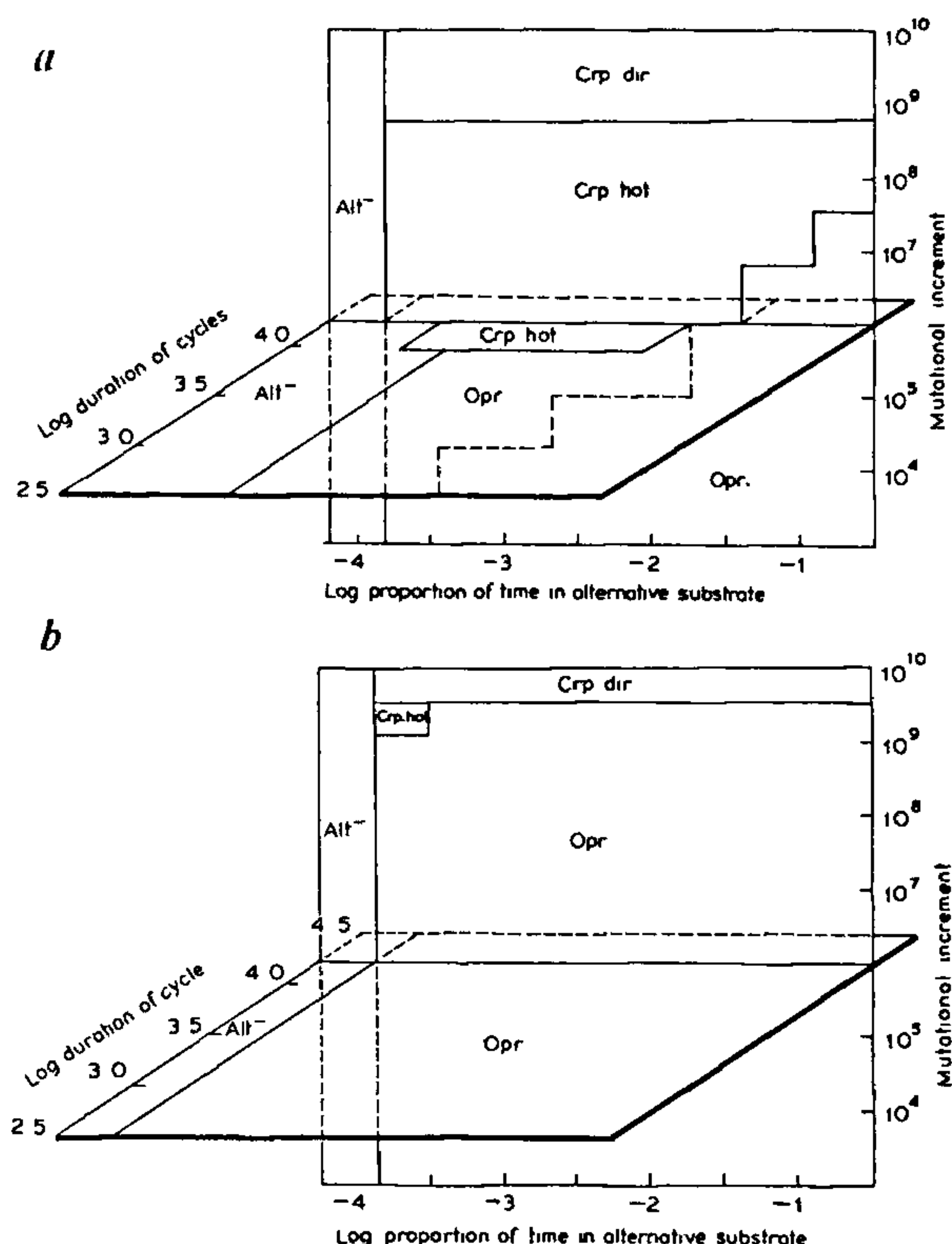

Figure 1. Areas of selective advantage to the four strategies. The figure represents a horizontal and a vertical slice from a three-dimensional phase space representing three parameters, viz. the proportion of time spent in the alternative environment, mutational increment and the periodicity of the cycle. *a*, At high selective pressures (dilution rate 0.16, i e. 80% that of the maximum growth rate of the highest-fitness genotype) the cryptic gene had a selective advantage over a wide range of conditions. Directed mutations, however, were advantageous only at unrealistically high mutational increments Cryptic genes with a mutational hotspot were better competitors than the ones with directed mutations. *b*, At low selective pressures (dilution rate = 0 016) the advantage to cryptic genes is lost Crp-dir gets selected at mutational increments of 10^{10}, which at this dilution rate means that at steady state the rate of directed mutations per cell generation is almost 1 Other parameters used here were $K = 1$; $L = 0\,00001$, $SRn/SRal = 10$; $F(Opr) = 0\,99875$, $F(Cn) = F(Hn) = 0\,99975$, $F(Aal) = 0.9975$; $F(Cal) = F(Hal) = 0.9985$ For other ranges of parameter values used in simulations (Appendix I), the results were qualitatively similar The areas of selective advantage to Crp-hot expanded or reduced depending upon the fitness costs assigned. However, Crp-dir was not selected at mutational increments of less than 10^8.

can make them active. It has been suggested that cryptic genes are maintained in bacterial populations by alterations between the 'normal' environment, in which there is selection against the expression of the gene, and an alternative environment in which there is selection favouring the expression of the gene[1-3]. Some of the cryptic genes studied have shown evidence of