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The Geology and Geochemistry of the Uda Walawe Serpentinite, Sri Lanka

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Abstract : Although two-thirds of the present nickel production is derived from nickel sulphides, lateritic nickel reserves are estimated to be around three times as those of sulphides. These vast reserves of lateritic nickel are expected in humid tropical terrains of the world where very little exploration work has been carried out. A lateritized serpentine body from Uda Walawe, Sri Lanka, has been studied for its geology and geochemistry. The nickel content shows a range of 0.05%-2% and occurs partly in the iron-oxide phase. Cobalt correlates well with manganese but there does not appear to be a significant correlation of nickel with magnesium and silicon. The chromium content ranged from 300-3100 ppm and was found mainly in the chrome spinels found in abundance in the serpentine body. Geologically, the Uda Walawe serpentinite body is located at a possible plate margin at the boundary of the Highland Group and the eastern Vijayan Complex and may well represent the more mobile part of an ophiolitic sequence.

1. Introduction

Nickeliferous laterites, serpentinites and other ultramafic bodies have recently been the subject of intensive study. The economic importance of laterites have been discussed at length[21] and special emphasis is now being laid on nickel bearing laterites.[14,22] Even a cursory glance at a map showing the distribution of tropical rain forests of the world where most laterites are expected to occur shows that the majority of them lie in developing countries. The utilization of lateritic nickel reserves is of particular importance to such developing countries in the tropical and sub-tropical regions where the largest reserves and resources of lateritic nickel occur. Although 62% of the present world production is derived from nickel sulphides,[15] the world nickel reserves in the laterites are considered to be three times as large as those of sulphides.[2] Even though the nickeliferous laterites are rather low grade resources, the large scale occurrences and possible complex utilization including the by-product recovery of Co, Cr, and Fe have triggered intense research work in many laboratories.[14] It is thus appropriate to term nickeliferous laterite as a resource of the future.

Lateritized serpentinites have been discovered in Sri Lanka recently[6,7] and they lie in the eastern sector of the island along the boundary of the Highland Group and the Vijayan Complex[17] (Figure 1). At present the mineral wealth of Sri Lanka consists mainly of non-metallic deposits[4,13] and in view of the many serpentine bodies found in Sri Lanka, exploration for nickel in these bodies is worthwhile.

2. Geologic setting

Geologically the greater part (about 92%) of Sri Lanka consists of rocks of Precambrian age, the island having remained stable over a long period of time. The Precambrian rocks have been classified into a Highland Group consisting mainly of rocks belonging to granulite facies, a Vijayan Complex of granites, granitic gneisses and migmatites of the amphibolite facies and a Southwestern Group, a complex of cordierite gneisses and charnockites (figure 1). For a detailed account of the geology of Sri Lanka, the reader is referred to Cooray.[3]

The serpentine bodies so far found in Sri Lanka all lie along the boundary of the Highland Group and the eastern Vijayan Complex. This boundary is now considered to represent the geosuture of an ancient plate margin and a potential mineralized belt.[16,17,18,19] Of these the Uda Walawe serpentine body is the best known and has been studied for its petrology and geochemistry[6,7] on a preliminary investigation. The serpentine body itself is approximately 7 km^2 in extent (Figure 2) and is surrounded by charnockites, calc-gneisses, migmatites and cordierite bearing gneisses. Along the northern contact of the body, diopside bearing gneisses and calciphyres could be recognized. In the eastern part of the area are hornblende-biotite gneisses and migmatites characteristic of the Vijayan Complex rocks.

Figure 3 illustrates the generalized cross-section of the lateritic serpentinite of Uda Walawe, Sri Lanka. The lateritic iron-ore cap is present at the top and is generally devoid of vegetation. This lack of vegetation in places where the lateritic cap is thick is very obvious and can easily be recognized in the aerial photographs covering such lateritic terrains. Below the lateritic cap are the remnants of the highly weathered serpentinized ultramafic rock which retains in most cases the original reticulate or banded structure. A conspicuous feature in this zone is the occurrence of small black grains of magnetite and chrome spinels. In a number of case histories,—India,[24] Thailand[20] and Cuba[11] this feature has been observed. It is also common to find the weathered ultramafic rock assuming varying shades of green. It is of interest to note that Brindley and Pham Thi Hang[1] observed a close correlation of the nickel content of serpentinite with the intensity of the green colour as determined by the Munsell colour chart. This feature is worthy of consideration during prospecting for nickel. Even the secondary silica minerals such as chert, agate, chalcedony, opal, etc., occasionally display shades of green colour which in some cases could be used as a guideline during exploration for nickeliferous laterites over serpentine bodies.

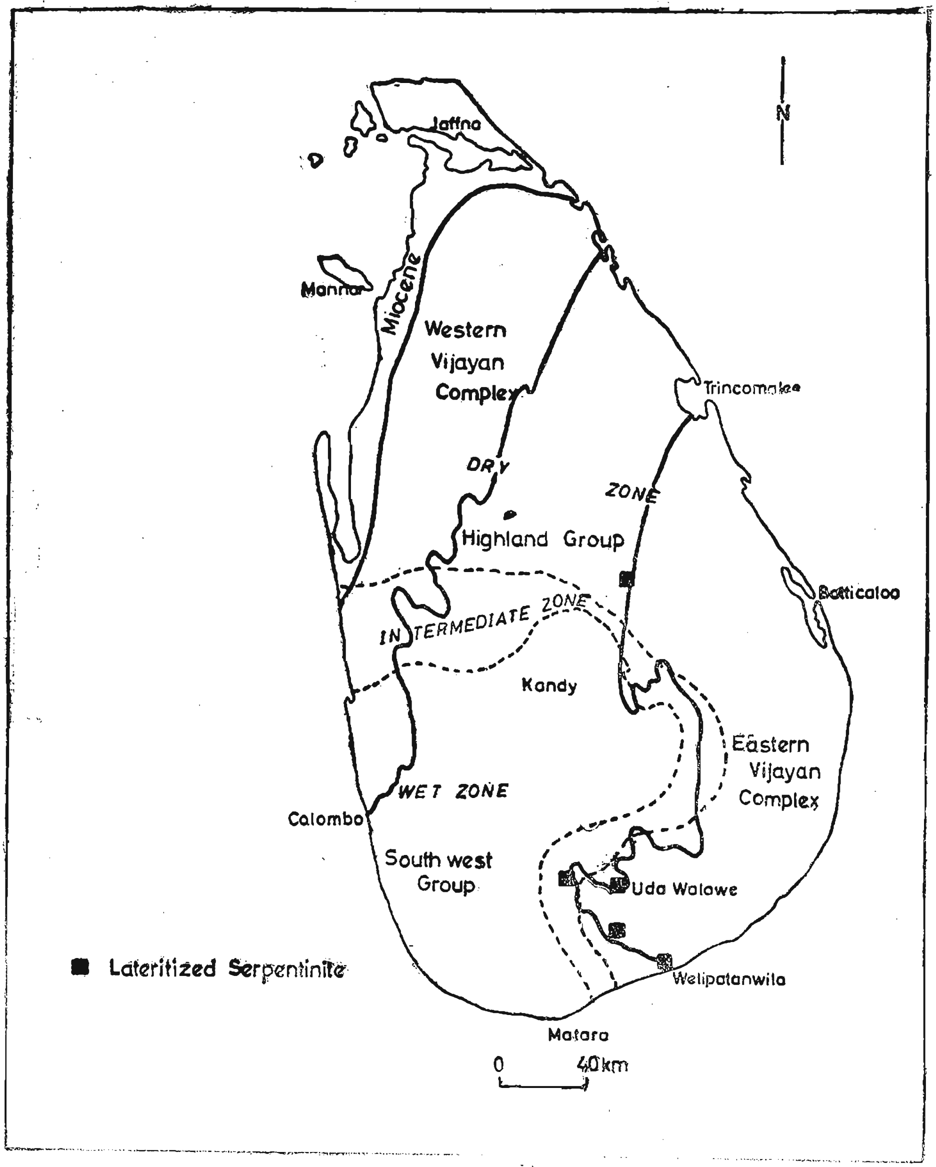

Figure 1. Map of Sri Lanka showing the main geological divisions and the climatic boundaries.

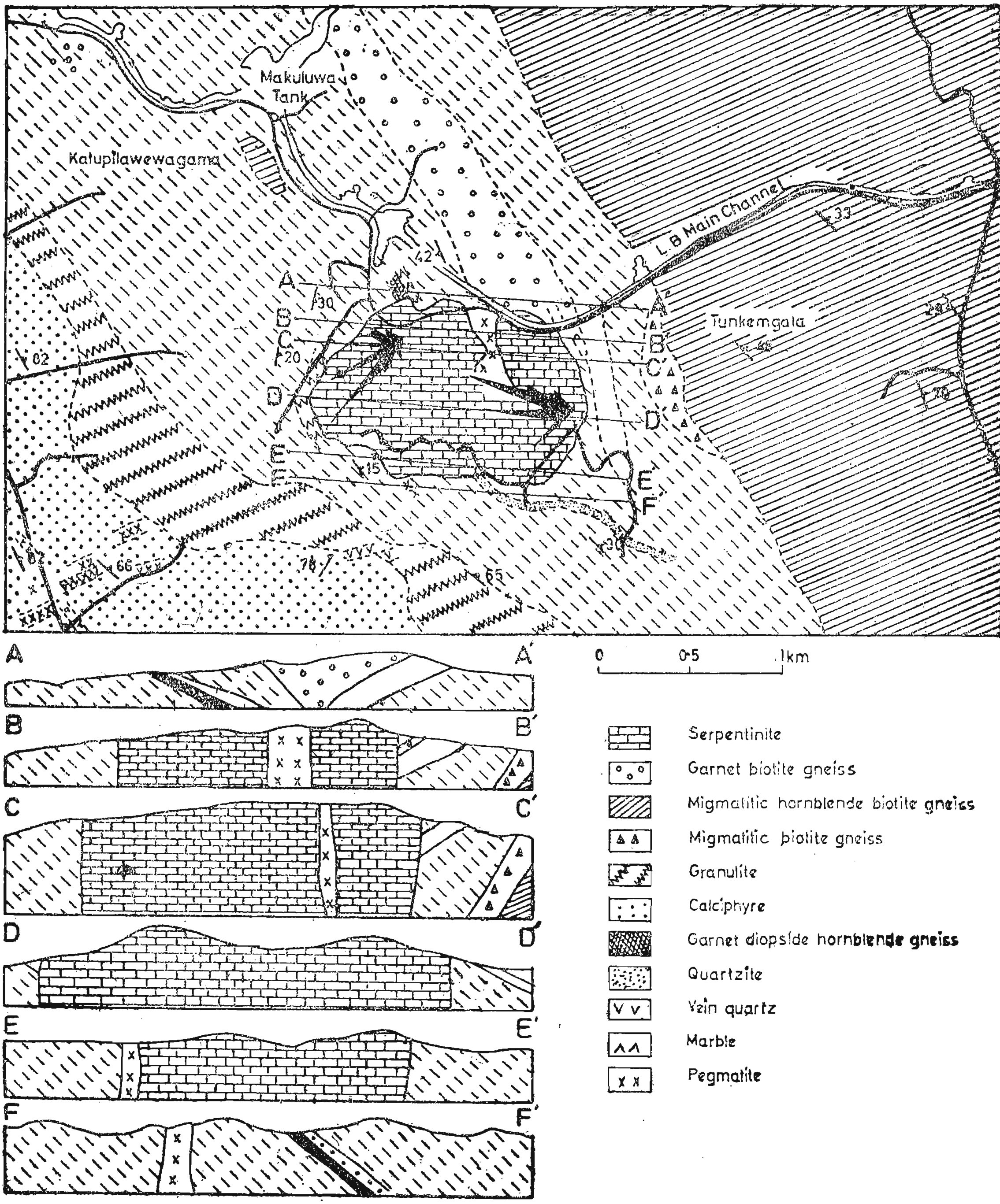

Figure 2. Geological map of the Uda Walawe serpentine body of Sri Lanka.

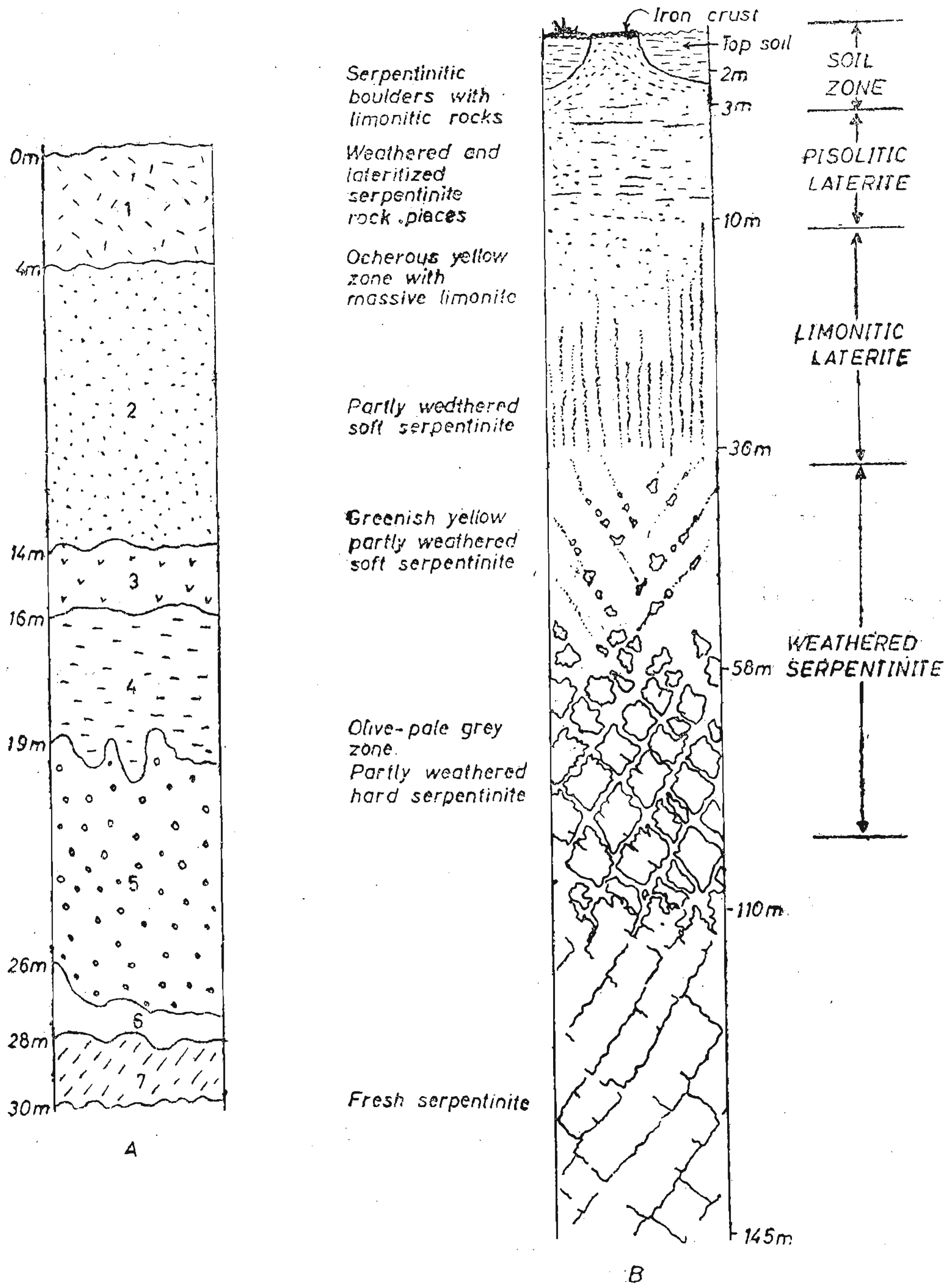

Figure 3A. Specimen geological section of a laterite in Sri Lanka

1 =	Humus rich soil material with iron concretions	5 =	bauxitic material
2 =	Coarse grained yellowish-brown soil material	6 =	reliefs of parent rock
3 =	Fine textured grey soil material (gibbsite abundant)	7 =	fresh bed rock
4 =	Iron-rich pebbly layer		

Figure 3B. Generalized profile of the Uda Walawe serpentinite of Sri Lanka.

The cumulate nature of the large grains of magnetite and spinels indicated a layered nature of emplacement for the Uda Walawe serpentinite body. Recent drilling of of the body by Geological Survey Department of Sri Lanka indicates a deep-seated origin and in view of the fact that these serpentine bodies are located at a possible plate margin[17] an ophiolitic origin cannot be ruled out. This is more so since the serpentine part is a more mobile section of an ophiolitic sequence. Geophysical work carried out on this body (M. J. Sarathchandra-personal communication) by the Water Resources Board also confirms a deep seated origin for the Uda Walawe serpentinite.

3. Petrology and Mineralogy

The rocks are completely serpentinized with some remnants of pyroxene and tremolite. Magnetite whenever present forms disseminated dust-like particles and the mafic dykes consist of tremolite/actinolite, diopside, enstatite and quartz. The serpentine is composed of fibrous and platy serpentine minerals (chrysotile and antigorite) associated with various amounts of silica and carbonates. Brown picotite/chromite concentrations are disseminated and where present are cut by small carbonate veins. In many sections a pale green, vesicular micaceous mineral (fuchsite, delessite) is present. According to textures and mineral associations the following serpentinites can be distinguished :[7]

(*a*) oolitic serpentinite, with oolitic silica and the micaceous mineral mentioned above,

(*b*) fibrous serpentinite. Compact vesicular antigorite and silica with or without dispersed carbonates,

(*c*) mesh-like serpentinite, with platy chrysotile and vesicular antigorite associated with carbonate and delessite or fuchsite. Chromite/picotite may or may not be present. This texture points to an original peridotitic composition,

(*d*) micaceous serpentinite, mainly composed of delessite or fuchsite.

Over 150 samples were taken on a grid sampling pattern and analyzed for the major and trace elements by X-ray fluorescence Spectrography at the University of Durham, U. K. and B. R. G. M., France.

Table 1 shows the normative mineralogy of 10 samples analyzed. As expected normative hypersthene and olivine are abundant and also a high water content. The differentiation index of the samples is very low and the Fe^{3+}/total Fe ratio remains constant at 0.25. Table 2 shows the mineralogical composition of a typical Uda Walawe serpentine sample.

TABLE 1. Normative mineralogy of the Uda Walawe serpentinite.

Summary Norm Table

	S1	S2	S3	S4	S4	S5	S5	S7	S7	S9	S9	S10
Orthoolase	0.1	0.1	0.3	0.5	0.5	0.3	0.3	0.0	0.0	0.0	0.0	0.2
Albite	0.3	0.5	0.3	0.4	0.2	0.2	0.2	0.4	0.0	0.3	0.2	0.4
Anorthite	0.5	0.6	0.3	0.5	1.0	0.9	0.3	0.6	0.6	0.4	0.7	0.5
Diopside	1.4	0.8	2.4	4.7	4.2	4.3	4.5	4.4	4.6	4.6	4.5	2.3
Hypersthene	46.2	42.2	78.9	71.3	71.9	85.0	85.0	53.6	53.7	72.0	71.0	81.1
Olivine	48.5	52.5	14.8	18.1	17.8	4.5	4.6	37.6	37.7	18.6	19.5	12.0
Magnetite	3.0	3.3	3.0	4.4	4·4	4.7	4.7	3.3	3.3	4.0	4.0	3.4
Ilmenite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apatite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water	12.1	12.1	8.3	10.8	10.6	11.0	11.0	11.3	11.4	12.7	12.3	9.1
Diff.Index	0.4	0.6	0.5	0.9	0.7	0.5	0.5	0.4	0.0	0.3	0.2	0.6
VA(NA+K)	0.70	0.38	0.53	0.46	0.30	0.43	0.43	0.95	0.60	1.00	1.00	0.67
(NA+K)/AL	0.32	0.31	0.49	0.46	0.26	0.20	0.23	0.28	0.01	0.76	0.13	0.36
F3(F2 + F3)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

4. Geochemistry

Table 3 shows the summary statistics of the elemental analyses for the Uda Walawe serpentine body.

4.1 Nickel

The nickel content of the lateritized Uda Walawe serpentinite shows a minimum nickel content of 500 ppm and a maximum of 2%. Figures 4–8 illustrate the variation of nickel with Fe_2O_3, MgO, SiO_2, Mn and the SiO_2/Fe_2O_3 ratio respectively. It seems apparent from these figures that nickel in the lateritized serpentinite shows a very slight preference for the iron-oxide phase, most likely a limonitic phase. The correlation coefficient for the variation of Fe_2O_3 with Ni is +0.60 whereas that of SiO_2 with Ni is +0.49 and is less significant. The SiO_2/Fe_2O_3 variation with nickel illustrates this further and seems to confirm a very slight preference of Ni for an iron-oxide phase. This slight association of nickel with iron indicates that goethite could also be a host for some of the nickel observed. Nickel can be found in the lattice of goethite, the substitution of trivalent iron by divalent nickel being facilitated by the simultaneous incorporation of tetravalent silicon. The variation of nickel with that of manganese is also only vaguely defined (correlation coefficient-0.48) and this appears to be in agreement with the conclusions of Schellmann[22] that less than one tenth of the nickel content is contained in the manganese oxide.

TABLE 2. Mineralogical composition of a typical Uda Walawe serpentine sample.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	TiO_2	P_2O_5	S	F	MnO	O-Excess
43.27	0.18	1.44	4.00	38.98	0.67	0.03	0.00	11.24	0.00	0.01	0.00	0.01	0.00	0.16	0.00

Table of cation atomic percentages

Si	40.46	Al 0.20	Fe^3 1.02	Fe^2 3.13	Mg 54.31	Ca 0.68	Na 0.05	K 0.00	Ti 0.01	P. 0.00	S 0.22
Mn	0.13	Zr 0.00	Cr 0.00	Li 0.00	Ba 0.00	Nb 0.00	Ni 0.00				

Table of normative mineral percentages

quartz	0.00	0.00	kaliophylite	0.00	0.00	wollastonite	0.00	0.00	titanite	0.00	0.00
corundum	0.00	0.00	halite	0.00	0·00	hypersthene	43.82	42.89	perovskite	0.00	0.00
zircon	0.00	0.00	therardite	0.00	0.00	olivine	50.45	52.51	rutile	0.00	0.00
orthoclase	0.00	0.00	sod. carb.	0.00	0.00	cal. orthosil	0.00	0.00	apatite	0.00	0.00
albite	0.29	0.27	acmite	0.00	0.00	magnetite	2.35	1.52	fluorite	0.00	0.00
anorthite	0.49	0.36	sod. metasil	0.00	0.00	chromite	0.00	0.00	pyrite	0.02	0.00
leucite	0.00	0.00	pot. metasil	0.00	0.00	hematite	0.00	0.00	calcite	0.00	0.00
nepheline	0.00	0.00	diopside	2.64	2.41	ilmenite	0.02	0.01	water	11.24	35.09

Other petrochemical functions

Ratio (mol.prop.) of MgO over total (MgO+ Fe) in ferromagnesian minerals = 0.95
Wt. % K metal = 67.59
Per alkalinity index = 0.27
Ratio (Na+) / (Na+) + (K+) = 1.00
Differentiation index = 0.29
Colour index = 99.29
Coordinates in SiO_2 - Al_2O_3 - (Na_2O + K_2O) (mol.prop.) . Silica = 99.69 alumina = 0.25 alkales = 0.07
Total olivine = 50.45 consisting of Fe 47.02 plus Fe 3.43
Total orthopyrosene = 43.82 consisting of En 41.10 plus Fs 2.72
Composition of clinopyroxene by Wt . wollastonite = 1.40 Enstatite = 1.16 Ferrosilite = 0.08
Composition of feldspar by Wt : orthoclase = 0.00 albite = 41.59 anorthite = 58.41
Molecular composition of feldspar : orthoclase = 0.00 albite = 43. 04 anorthite = 5.6964 3E + 01
Iron oxidation ratio Fe_2O_3/(FeO + Fe_3O_3) = 26.51%
Ratio K_2O/(Na_2O + K_2O) = 0.00%

CO-ORDINATES IN THE SYSTEM PLAGIOCLASE – QUARTZ – OLIVINE – DIOPSIDE : Wt. % REPRESENTED BY THIS SYSTEM = 97.60%

	Component Wt.%	Mol. Prop.%	Mol. Cat.%
Plagioclase	0.71	0.25	0.65
Quartz	18.24	27.04	10.89
Olivine	83.35	71.19	89.01
Diopside	2.70	1.52	2.45
Diopside projection			
Plagioclase	0.73	0.26	0.66
Quartz	13.60	27.46	11.17
Olivine	85.67	72.28	88.17
Olivine projection			
Plagioclase	4.25	0.87	4.62
Quartz	79.52	93.85	77.87
Diopside	16.22	5.28	17.51
Quartz projection			
Plagioclase	0.82	0.34	0.72
Olivine	96.07	97.57	96.53
Diopside	3.11	2.08	2.75
Plagioclase projection			
Quartz	13.33	27.11	10.96
Olivine	83.95	71.36	86.57
Diopside	2.72	1.52	2.47

Table 3. Summary statistics of the elemental analyses for the Uda Walawe serpontine body.

	Si	Al	Fe	Mg	Ca	Na	K	Ti	Mn	P
MEAN	44.960	0.220	8.483	34.301	1.390	0.030	0.018	0.020	0.222	0.003
VAR	16.610	0.023	1.724	14.654	14.025	0.000	0.000	0.004	0.009	0.000
SDEV	4.075	0.150	1.313	3.828	3.745	0.014	0.019	0.064	0.096	0.005
MAX	63.710	1.110	11.560	40.210	35.580	0.070	0.139	0.600	0.637	0.020
MIN	24.100	0.040	5.360	15.360	0.002	0.001	0.000	0.000	0.071	0.0.00
	S	Fe_2	H_2O	Ba	Nb	Zr	Y	Sr	Rb	Zn
MEAN	0.017	5.768	10.389	10.700	2.600	1.420	1.160	6.070	1.350	78.930
VAR	0.000	0.798	2.561	276.730	1.520	3.224	0.734	79.645	0.727	1454.765
SDEV	0.009	0.893	1.600	16.635	1.233	1.795	0.857	8.924	0.853	38.141
MAX	0.000	7.860	14.350	100.000	5.000	10.000	4.000	80.000	4.000	246.000
MIN	0.000	3.640	4.140	0.000	0.000	0.000	0.000	1.000	0.000	34.000
	Cu	Ni*	Pb	Th	Cr	Ga	La	Ce		
MEAN	4.190	4831.420	3.100	2.250	1819.340	1.620	4.880	19.200		
VAR	17.054	5780.424	3.450	4.647	3794.484	1.756	4.006	30.120		
SDEV	4.130	2786.715	1.857	2.156	666.179	1.325	2.016	5.488		
MAX	23.000	24067.000	7.000	9.000	3146.000	5.000	16.000	46.000		
MIN	0.000	555.000	0.000	0.000	373.000	0.000	0.000	1.000		

*Ranges for nickel concentrations.

number of samples	Ni ppm
20	500—1000
105	1000—4000
20	4000—10,000
10	10,000—20,000

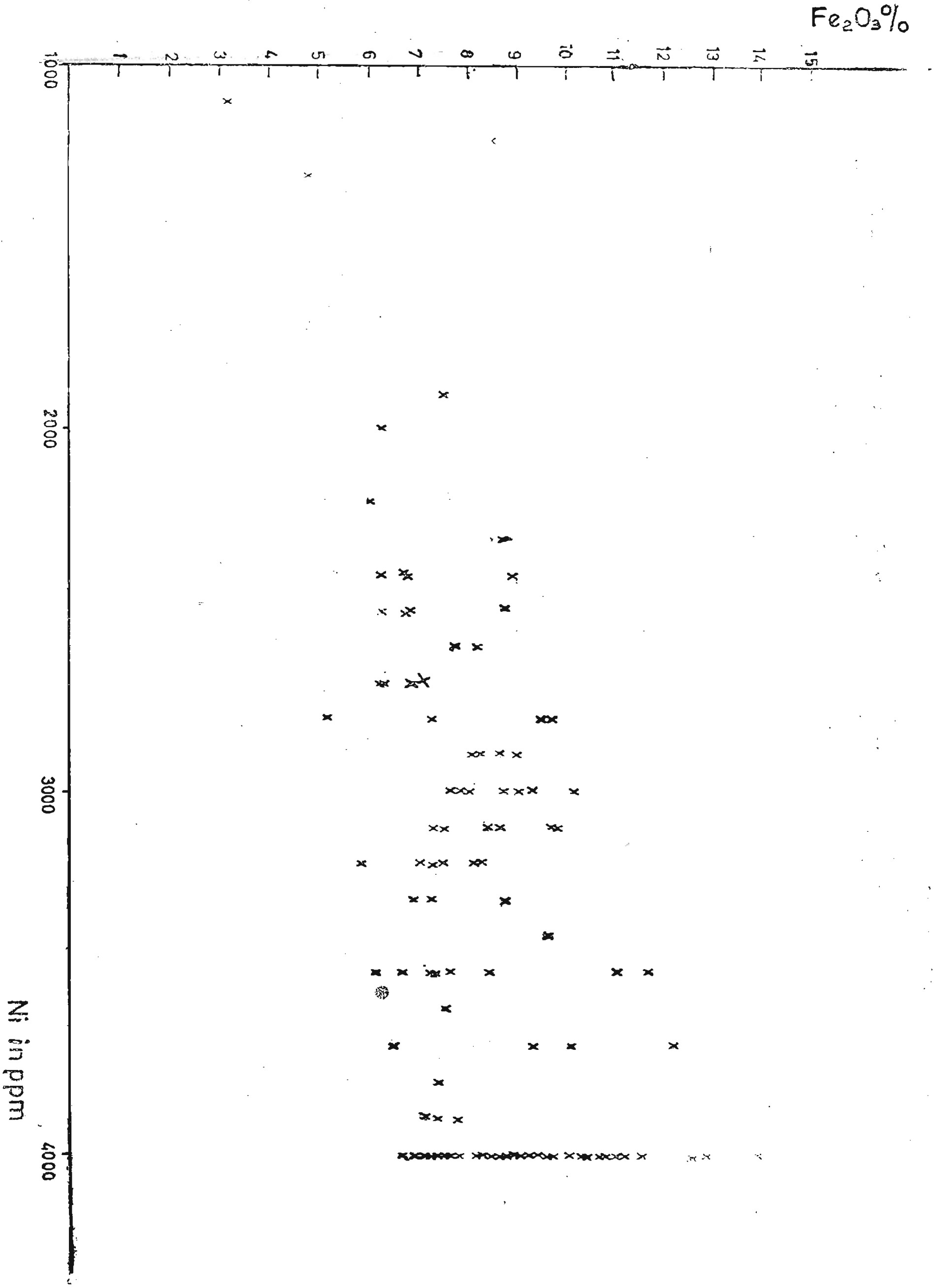

Figure 4. Variation of Ni with Fe_2O_3 in the lateritic serpentine samples

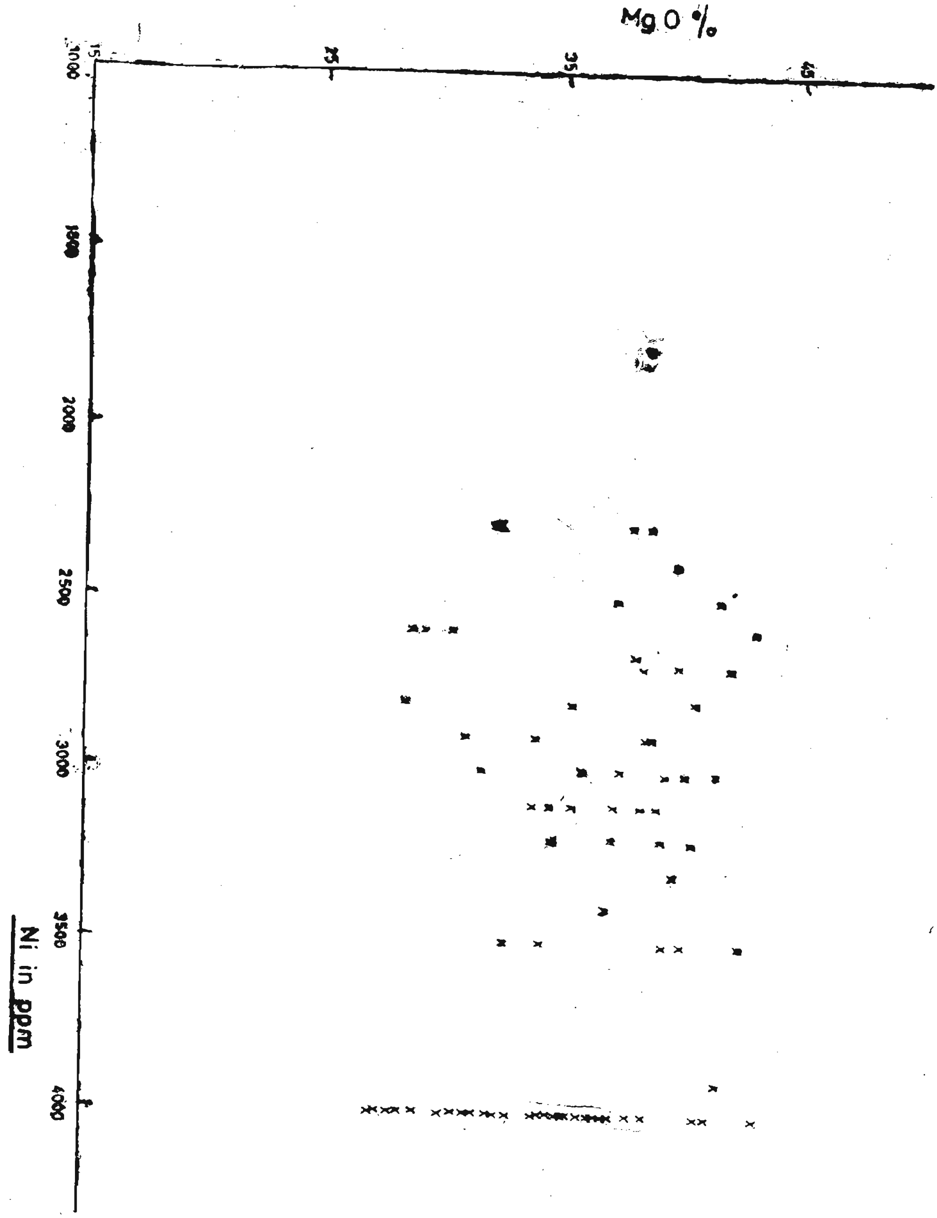

Figure 5. Variation of Ni with MgO in the lateritic serpentine samples

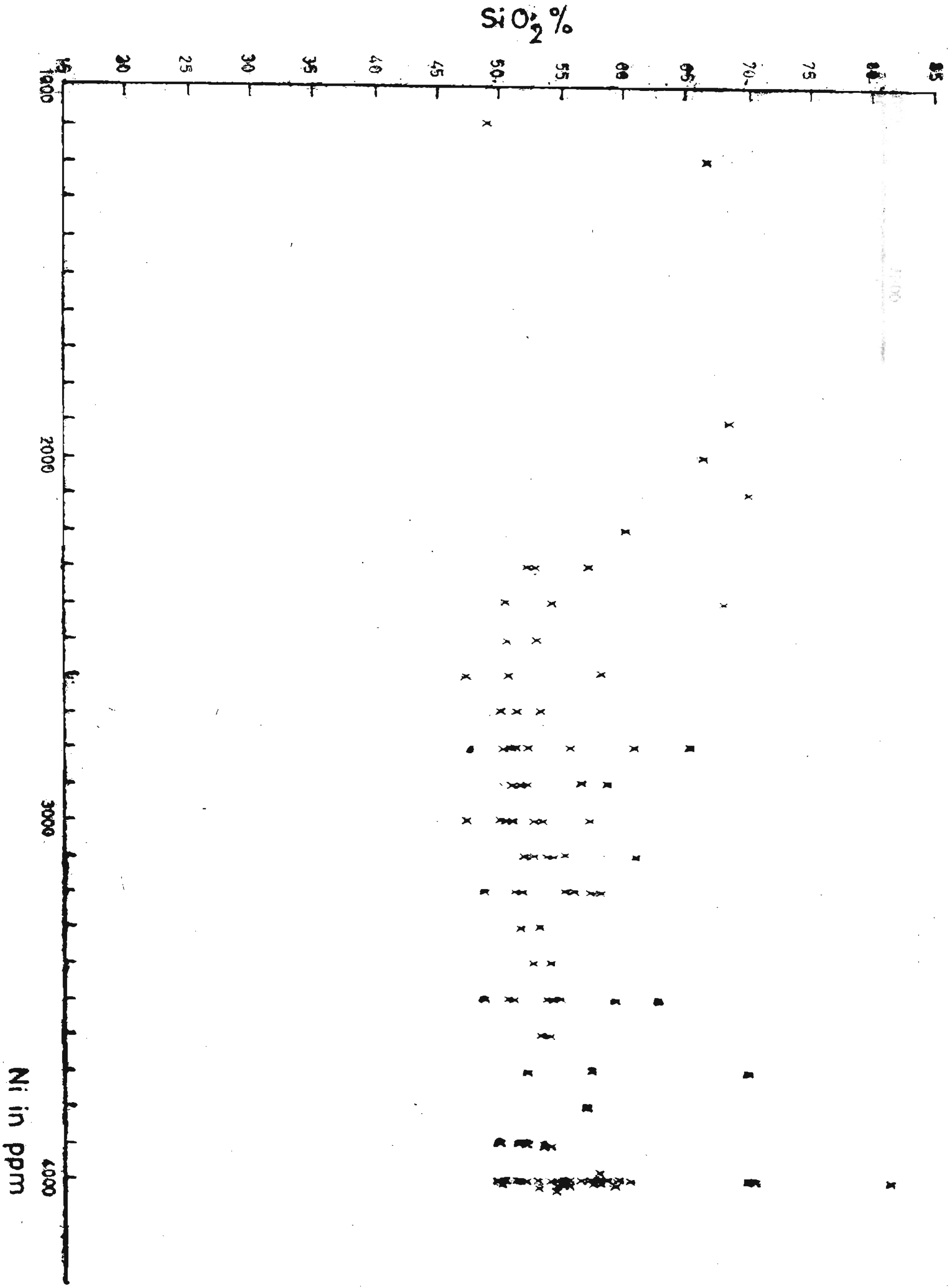

Figure 6. Variation of Ni with SiO_2 in the lateritic serpentine samples.

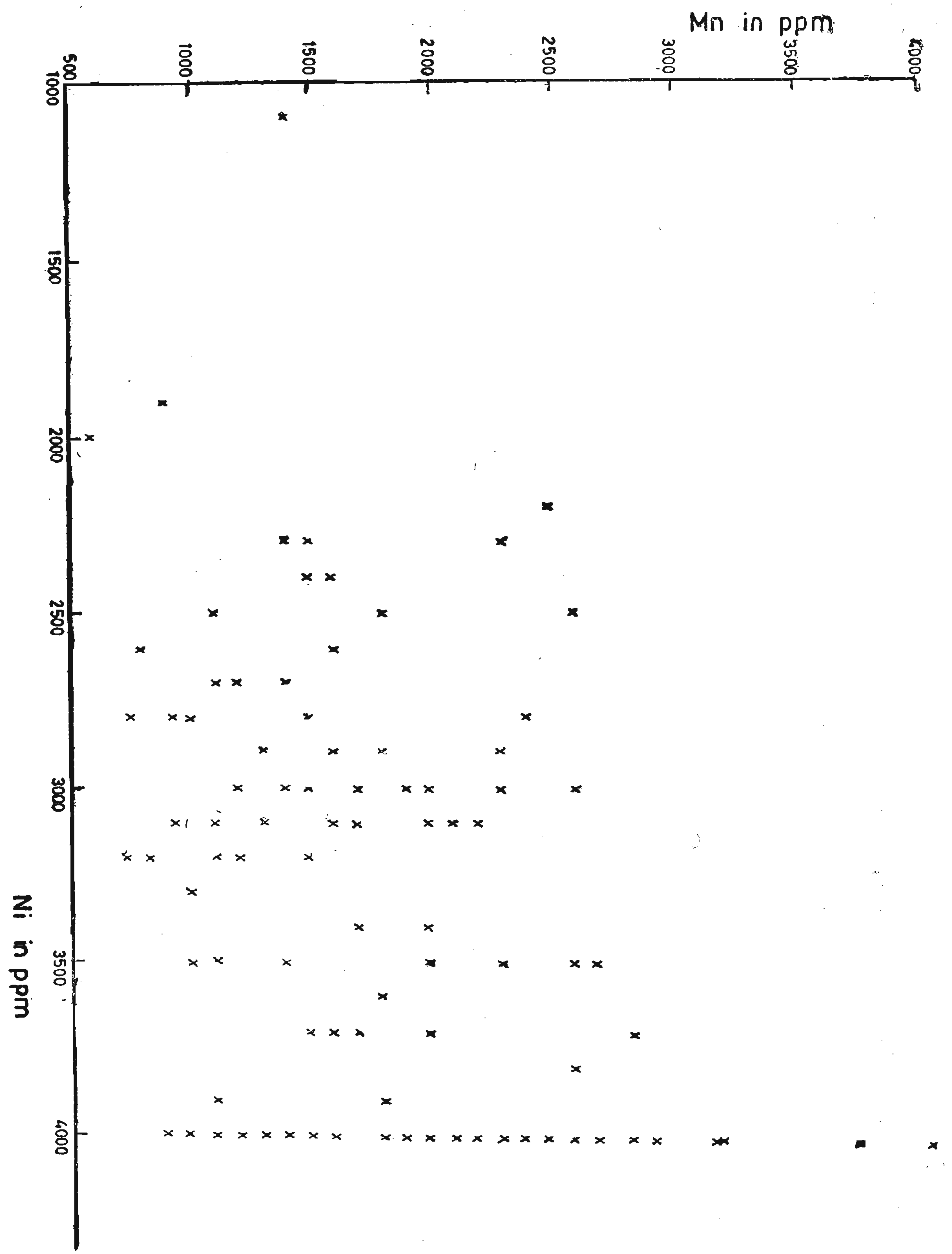

Figure 7. Variation of Ni with Mn in the lateritic serpentine samples.

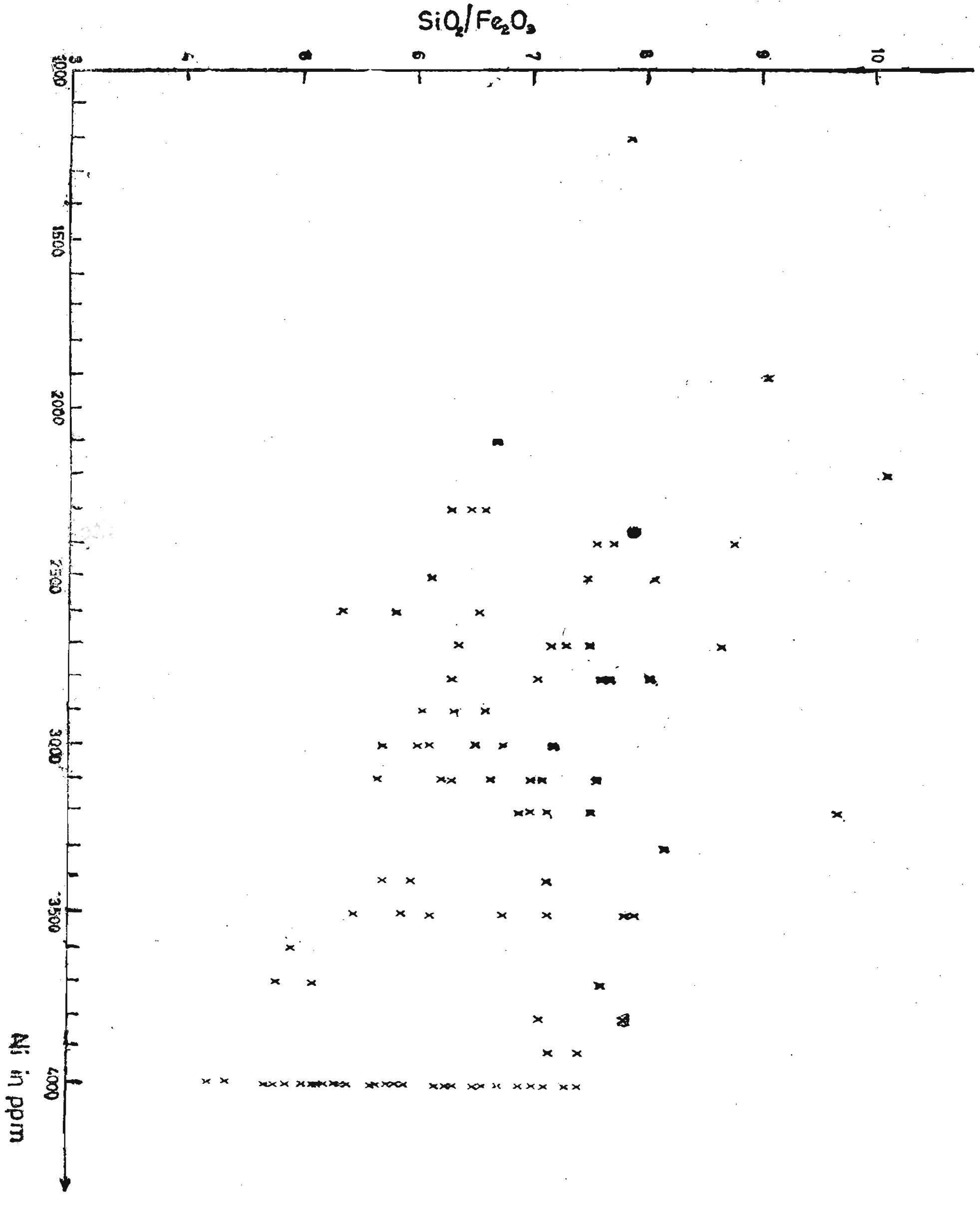

Figure 8. Variation of Ni with SiO_2/Fe_2O_3 in the lateritic serpentine samples.

A further noteworthy feature observed in the distribution of nickel in the serpentinite was the high average NiO content (1.15%) of the spinels. Based on the chemistry the spinels were classed as ferritchromites. Table 4 shows the electron-probe microanalyses of spinels from the Uda Walawe serpentinite. With serpentinization and alteration the Al_2O_3, MgO and Cr_2O_3 contents had decreased while an increase of total Fe and NiO were observed. It appears very likely that the unlateritized parent rock did not have a sulphide rich phase as Ni will then move preferentially with sulphides. The correlation diagrams were restricted to the samples containing nickel in the range 1000-4000 ppm, since those with higher Ni contents consisted mainly of spinels.

4.2 Cobalt

Figure 9 illustrates very clearly the close association of Co with Mn. This association has been noted in many previous studies on laterites.[5,9]

The manganese oxides are known mostly to fill out small cavities and fissures in the limonitic matrix, indicating their secondary precipitation. In the Uda Walawe serpentinite, the cobalt values as analyzed by quantometry (B. R. G. M) ranged from 70-380 ppm. Figure 10 illustrates the Ni-Co-Cr variation in the serpentinite.

4.3 Chromium

The chromium content ranged from 300-3100 ppm and was mainly found in the chrome spinels. Electron-probe microanalyses of a number of spinels separated from the serpentinite showed an average content of 9.47%. Schellmann[22] showed from analytical results for 8 nickel limonitic ores from various deposits around the world that 55-75% of the chromium is bound in chrome spinels and since the stability of chrome spinels is high, the geochemical mobility of chromium during tropical weathering is also low.

4.4 Manganese

The manganese content of the samples ranged from 700-6300 ppm and was mainly found in the limonitic material. Mn occurs as MnO_2 coatings and films on joint planes in the limonitic lateritic zone characterized by its lack of parent rock texture and its mineralogy.

4.5 Zinc and lead

At present there are very little data on the zinc and lead contents of serpentinites. A zinc content of 2000 ppm was reported by Faust and Fahey[10] and Zelissink[23] reported a zinc content of 32 ppm for the Greenvale serpentinite of Queensland. In this study the zinc content ranged from 30-250 ppm in the samples investigated. Zinc on account of its tendency to enter into 4 fold co-ordination in minerals[8] prefers the the spinels and other iron-oxide minerals.

TABLE 4A. Electron-probe microanalyses of spinels from the Uda Walawe serpentinite.

	Mg	Al	Ti	V	Cr	Mn	Fe	Ni	Total
Point I									
BG	1.02	2.88	18.84	24.23	32.66	40.45	3.74	3.94	
CI	2.16	0.36	0.01	0.04	6.98	0.05	64.23	0.88	
BC	3.59	0.67	0.02	0.07	10.21	0.06	82.64	1.12	
AC	5.59	0.86	0.02	0.06	9.34	0.06	76.35	1.14	93.43
Point 2									
BG	1.38	4.85	18.45	23.55	30.84	41.79	4.82	3.38	
CI	2.11	0.33	0.01	0.05	7.21	0.05	65.63	0.92	
BC	3.50	0.63	0.02	0.09	10.53	0.07	84.43	1.17	
AC	5.46	0.80	0.02	0.09	9.64	0.07	77.99	1.20	95.26
Point 3									
BG	0.92	3.91	15.34	22.29	31.88	39.34	3.27	3.74	
CI	2.09	0.34	0.04	0.05	7.02	0.05	65.97	0.88	
BC	3.46	0.65	0.06	0.09	10.25	0.07	84.87	1.11	
AC	5.39	0.84	0.07	0.09	9.38	0.07	78.38	1.13	95.35
Point 4									
BG	0.92	2.15	17.72	23.93	31.16	42.27	5.23	4.18	
CI	2.23	0.45	0.03	0.06	7.09	0.05	65.99	0.83	
BC	3.70	0.86	0.04	0.10	10.37	0.06	84.89	1.05	
AC	5.76	1.10	0.04	0.09	9.50	0.06	78.46	1.07	96.09
Point 5									
BG	1.86	3.02	17.33	25.23	37.99	39.46	2.91	3.91	
CI	2.14	0.43	0.03	0.40	7.01	0.05	66.27	0.84	
BC	3.55	0.80	0.04	0.06	10.24	0.07	85.15	1.07	
AC	5.54	1.04	0.04	0.06	9.37	0.07	78.75	1.09	95.95
Point 6									
BG	1.39	1.39	17.79	25.58	35.13	37.98	3.68	4.05	
CI	2.00	0.43	0.02	0.03	7.19	0.05	66.11	0.95	
BC	3.32	0.82	0.04	0.05	10.51	0.07	85.05	1.21	
AC	5.18	1.05	0.04	0.04	9.61	0.07	78.54	1.23	
Point 7									
BG	0.70	1.39	17.29	24.77	35.86	41.33	5.03	4.71	
CI	2.16	0.38	0.03	0.04	6.96	0.05	66.29	0.89	
BC	3.57	0.71	0.04	0.06	10.18	0.06	85.27	1.13	
AC	5.57	0.91	0.04	0.06	9.31	0.06	78.75	1.15	95.86
Point 8									
BG	1.39	4.18	17.22	24.89	30.27	43.04	4.45	3.99	
CI	2.26	0.33	0.03	0.04	7.14	0.05	66.23	0.91	
BC	3.74	0.63	0.04	0.06	10.43	0.07	85.20	1.15	
AC	5.83	0.81	0.04	0.06	9.55	0.07	78.72	1.17	96.25
Av. Comp.									
SD	0.09	0.05	0.01	0.01	0.09	0.00	0.65	0.04	
CI	2.16	0.38	0.02	0.04	7.03	0.05	65.88	0.89	
BC	3.57	0.71	0.04	0.07	10.35	0.06	84.76	1.13	
AC	5.57	0.91	0.04	0.06	9.47	0.06	78.30	1.15	95.55

BG: Background
CI: Metal%
BC: as oxide
AC: Oxide % with all correlations
SD: Standard deviation

TABLE 4B. Structural parameters for the spinels from the Uda Walawe serpentinite.

Uda Walawe Spinel Recalculation N = 8 Sum = 95.5 V = 00.06

Spinel analysis Wt. %

SiO_2 : 0.0 TiO_2 : 0.040 Al_2O_3 : 0.910 Cr_2O_3 : 9.470 Fe_2O_3 : 0.0 MnO : 0.050 MgO : 5.570 Na_2O : 0.0 K_2O : 0.0
NiO : 1.150 FeO : 78.300 CaO : 0.00

Cation proportions Si : 0.0 Ti : 0.036 Al : 1.287 Cr : 8.968 Fe^3 0.0 Fe^2 78.577 Mn : 0.061 Mg : 9.96 Ca : 0.0 Na : 0.0 K : 0.0
Ni : 1.110

Sum of cations to 32 oxygens : 30.429

Oxidation ration : 0.0

Differentiation index, cation proportions : 11.250

Chrome spinel parameters after Irvine : Mg/Mg + Fe^2 = 0.113 Fe^3/Cr + Al + Fe^3 = 0.00 Cr/Cr + Al = 0.874

Structural formula Si : 0.0 Ti : 0.011 Al : 0.392 Cr : 2.729 Fe^3 : 0.0 Fe^2 : 23.910 Mn : 0.019 Mg : 3.031 Ca : 0.0 Ni : 0.338

End-member proportions	Excess Fe^2 or Fe^3 iron in Irvine end-member recalculation scheme, Fe_2O_3 : 0.0 FeO : 74.082 calculated to 32 oxygens	Fe^2 and Fe^3 iron have been redistributed to give no residual recalculation of magnetite oxidation ratio thus produced = 62.804	Fe^2 and Fe^3 iron have been redistributed to give sum cations = 24.00 Residual FeO = 0.006 Fe_2O_3 = 0.0
Ulvospinel $Fe^2 2TiO_4$	0.699	0.121	0.108
Chromite $Fe^2 Cr_2O_4$	86.836	15.018	13.453
Magnesiochromite $MgCr_2O_4$	0.0	0.0	0.0
Spinel $MgAl_2O_4$	12.465	2.156	1.931
Hercynite $Fe_2Al_2O_4$	0.0	0.0	0.0
Magnesioferite $MgFe_2^3,O_4$	0.0	0.0	31.283
Magnetite $Fe^2Fe_2^3O_4$	0.0	82.705	53.225

Analysis of spinel with sum of cations : 24.00

SiO_2 : 0.0 TiO_2 : 0.40 Al_2O_3 : 0.910 Cr_2O_3 : 9.470 Fe_2O_3 : 62.383 FeO : 22.163 MnO : 0.060 MgO : 5.510 CaO : 0.0 Na_2O : 0.0
K_2O : 0.0 NiO : 1.150

Cation Proportions

Si : 0.0 Ti : 0.036 Al : 1.287 Cr : 8.968 Fe^3 : 56.335 Fe^2 : 22.241 Mn : 0.061 Mg : 9.961 Ca : 0.0 Na 0.0 K : 0.0 Ni : 1.110

Sum of cations to 32 oxygens : 24.000

Oxidation ratio; 71.695

Chrome spinel parameters after Irvine : Mg/Mg + Fe^2 = 0.009 Fe^3/Cr + Al + Fe^3 = 0.846 Cr/Cr + Al + 0.874

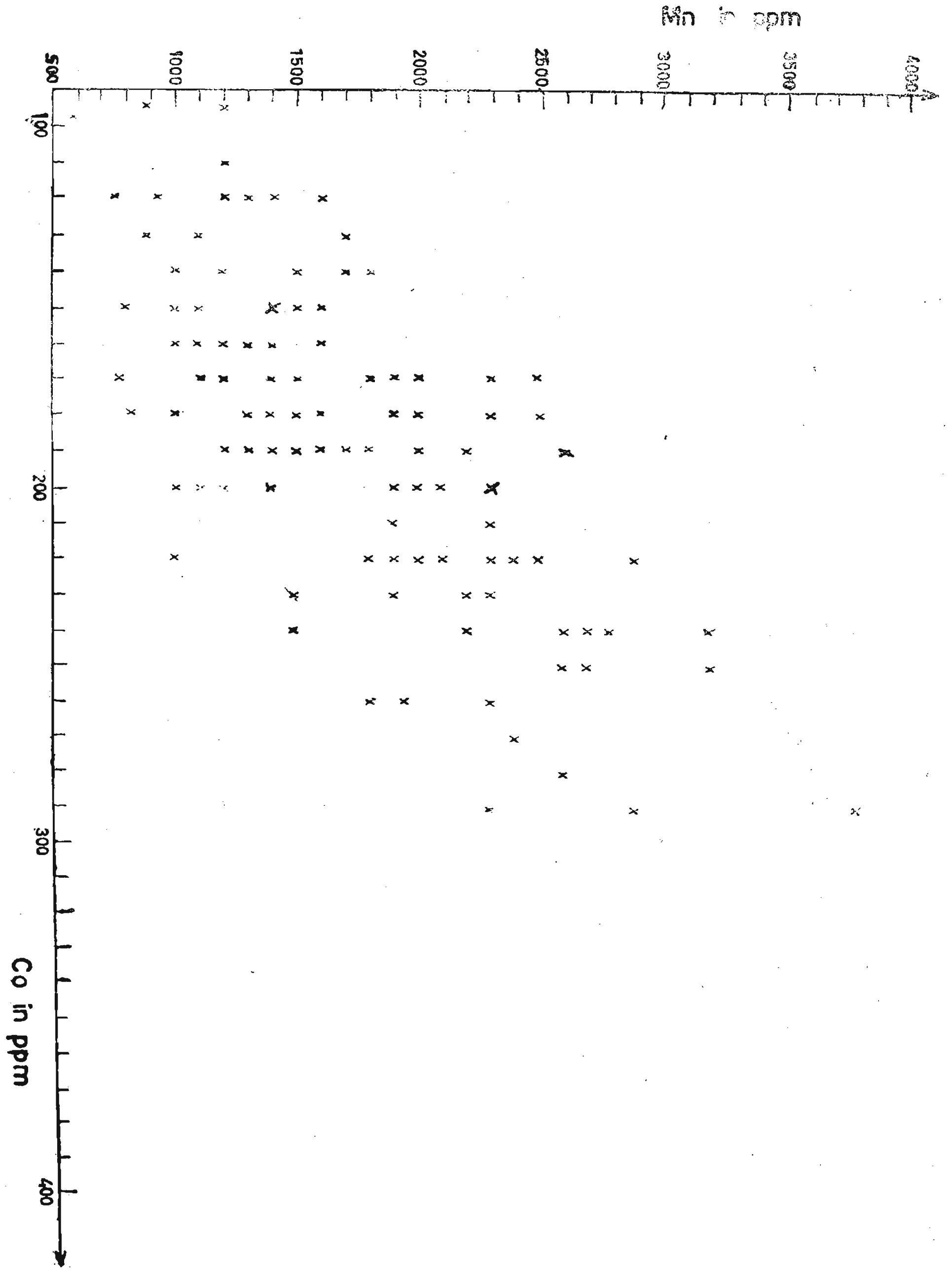

Figure 9. Variation of Co with Mn in the lateritic serpentine samples.

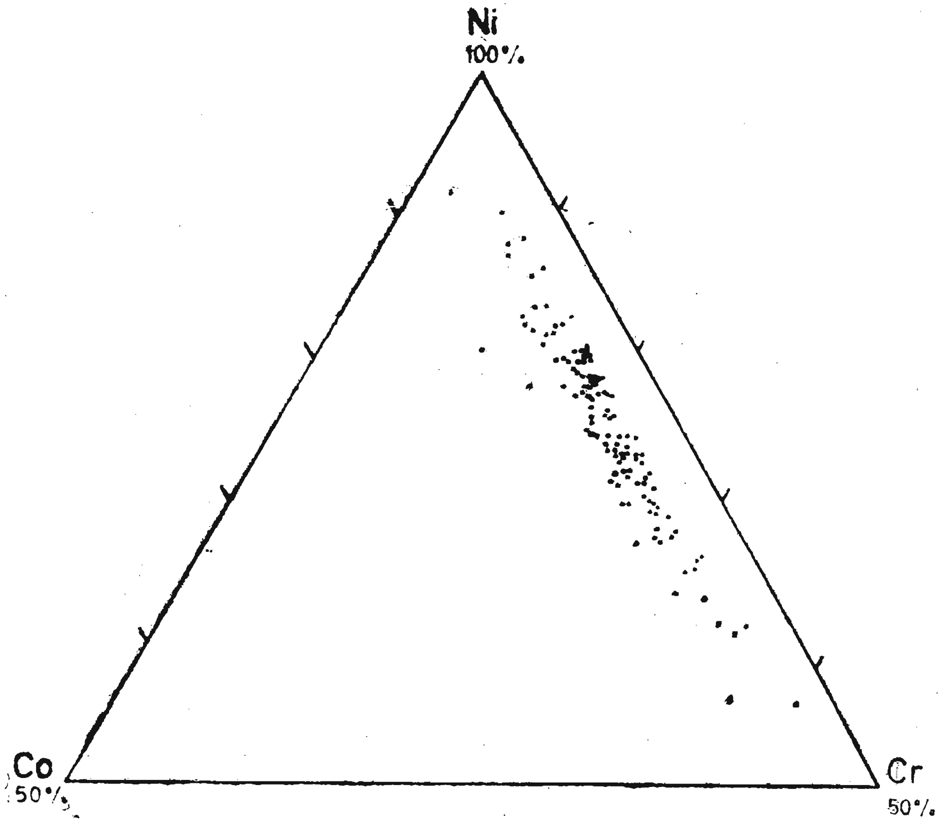

Figure 10. Relative concentrations of Ni, Co and Cr in the lateritic serpentine samples.

In the case of lead there is a severe dearth of data. Zeissink[23] has reported lead contents of 6 and 9 ppm for the Greenvale and Rockhampton serpentinite bodies respectively. In this study, the lead contents varied from 0-7 ppm.

4.6 Zirconium

The available data on zirconium on serpentinites indicate a paucity of the element. Hahn-Weinheimer and Rost[12] and Faust and Fahey[10] reported values of 2 ppm whereas Zeissink[23] reported a much higher value of 84 ppm Zr. This work shows a maximum of 10 ppm Zr for the Uda Walawe serpentinite and since no zircon was identified in the samples, it is presumed that Zr is associated with Ti.

5. Conclusions

Tropical rain forests which cover nearly 23 million km^2 of the earth's surface lie mainly in the Indonesia-S.E Asia region and West Central Africa, Amazon Basin South Central America region and a few others. The mineral potential of these areas is probably as large as that of equivalent geological areas in other climatic environments. However, very little exploration work has been carried out in these regions and the techniques for finding new mineral deposits in these areas are still in a primitive stage of development. This case study on the Uda Walawe serpentinite of Sri Lanka—a country which has very little sizeable metal bearing deposits, illustrates the mineral potential of such lateritized regions in the tropics.

The Uda Walawe serpentinite demonstrates the need for much more detailed studies on the economic evaluation of the serpentinites of Sri Lanka.

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