Nickeliferous deposits have been known in Brazil from about a century ago. These ores are lateritic weathering products of ultramafic rocks. They occur between 8° and 25° South, most are in Goias State, central Brazil. The Brazilian ultramafic rocks can be related to at least three orogenic cycles: Early Precambrian; Late Precambrian and Cretaceous. All of these ultramafic rocks are partially or completely serpentinised. There are other small Precambrian (age not established) mineralised massifs: Americano do Brasil, Goia, Sanclerlandia, Go, Carajas, PA.

Brazilian nickeliferous deposits occur in varied conditions of relief and climate. Their formation can be related to the Early Tertiary “South American erosion cycle”. The weathering products of this cycle are lateritic, with residual concentration of iron, but show silica accumulation (chalcedony, quartz) as silicifies over ultramafic rocks. This silicifies, often of the “box-work” type, apparently formed at the bottom of Tertiary profiles and was later exposed by erosion (“Velhas cycle”, Late Tertiary). Beneath the silicifies, a new profile, lateritic or saprolitic, formed. Erosion slopes and especially the lower, new-formed plains have weathered according to more recent climatic conditions, forming laterites in humid central Brazil, and saprolites in the arid Northeast. Brazil occupies the seventh position in the world in its estimated reserves of nickel ore (4.40° tons Ni in 1975). The main features of these deposits are:

- Initial stage of lateritic weathering in Early Tertiary.
- Important silicification related to this cycle.
- The silicified ore-type predominates over the limonitic type, as a result of post-Tertiary tectonomorpho climatic evolution.

Thus, Brazilian nickeliferous deposits are different from the majority of other lateritic deposits in the world.

INTRODUCTION

According to their conditions of formation nickel deposits are of two types (Lombard, 1956 and Boldt, 1967): sulfide deposits of hypogene origin, and lateritic deposits of supergene origin. Nickeliferous laterites constitute a thick weathering cover of ultramafic rocks in tropical areas.

Some sulfides of copper and nickel have been prospected in Brazil (for example in the Sao Joao massif, at Americano do Brasil-Goias). But all the Brazilian nickeliferous reserves are in lateritic weathering products of ultramafic rocks.

Ultramafic massifs occur in the majority of the Brazilian states, from the equator to 32°S latitude. However, three areas show a higher density of ultramafic rocks (Fig.1) (Berbert, 1977).

A central band, elongated N-S: in Goias and continuing to the state of Para; the largest Brazilian massifs and the best nickel ore reserves are here (Fig.2) (Angeiras, 1968; Godey, 1968, Lindenmayer and Lindenmayer, 1971; Vasconcellos, 1973).

A second area in Northeast Brazil, mainly in the state of Bahia.

And a third area in the state of Minas Gerais in Southeastern Brazil. The Amazon Basin is very poorly known, which explains the apparent absence of ultramafic rocks in the northeastern part of the country, covered by a great equatorial forest.
layered mafic-ultramafic rocks with a probable Archean age (perhaps as old as 4 billion years—Costa and et al., 1970), and great size. There are three massifs: Barro Alto, Niquelandia and Canabrava (and perhaps a fourth to the north in Natividade—Berbert, 1977), each being about one hundred km long, and forty km wide, although the ultramafic zone is much smaller. Four main layers can be distinguished in the massifs (Araujo et al., 1972; Figueredo et al., 1972; Souza, 1973), with a westward dip:
(i) A noritic basal zone (with some Cu and Ni disseminated sulfides)
(ii) An ultramafic zone, 2000 m thick (dunite, peridotite, pyroxenite, always more or less serpentined, and some pod-shaped bodies of chromite—White et al., 1971).
(iii) A central zone with xenoliths (Niquelandia) or anorthosite (Barro Alto).
(iv) A top zone with gabbro.
The old massifs show both "Alpine" features (mainly in the bottom part) (Thayer, 1972), and "stratiform" features (at the top) (Fleisher and Routhier, 1970).

(i) The small Alpine-type massifs of varied ages (Almeida, 1978): Small bodies, from a few metres to several kilometres in size, are disposed in "serpentine belts". But the majority of these massifs is attributed to a geotectonic model of a "greenstone belt" with a N-S orientation. These small massifs contain hornblendites, serpentinitised peridotites, actinolite-tremolite-talc-chlorite schists. Two Transamazonian massifs of pyroxenites and gabbroic gneisses are considered similar to the ultramafic rocks of Bahia: Gofra-Trinidade in Golas (Lindermayer and Oliveira, 1970) and Pern in Para (Girard and Ulrich, 1978). They could have resulted from the fractional crystallisation of a tholeiitic magma.

(ii) The second type of ultramafic rocks occurs in the state of Bahia, associated with the Transamazonian Cycle (about 2000 million years). These massifs can be stratified as at Campo Fornos, with serpentinitised peridotites, chromitites, pyroxenites and gabbros (Heidberg, 1974; Gon Calves et al., 1973). But the majority of these massifs is attributed to a geotectonic model of a "greenstone belt" with a N-S orientation. These small massifs contain hornblendites, serpentinitised peridotites, actinolite-tremolite-talc-chlorite schists. Two Transamazonian massifs of pyroxenites and gabbroic gneisses are considered similar to the ultramafic rocks of Bahia: Gofra-Trinidade in Golas (Lindermayer and Oliveira, 1970) and Pern in Para (Girard and Ulrich, 1978). They could have resulted from the fractional crystallisation of a tholeiitic magma.

(iii) The great Archean massifs (Niquelandia): The sedimentary basin of the Archean massifs, in some Alpine-type massifs (Ponta Alta, Sao Joao do Piaui).

The stratiform massifs contain great reserves of chromite (Campos Fornos), and the "greenstone belt" type shows indications of Cu, Ni and Zn sulfides.

In the ultramafic-alkaline massifs, deposits of vermiculite, phosphate, niobium, rare earths and uranium occur.

Table I gives the size, reserves, and average nickel grade of the main nickel deposits. It emphasises the importance of the state of Goias. In spite of the presence of ultramafic rocks elsewhere, there are few nickel deposits in other states; as will be shown later, recent morpheo-climatic evolution explains the distribution of the Brazilian nickel.

Recent morpheo-climatic conditions

The economic accumulation of nickel in a weathering profile (nickeliferous laterite) is a result of the convergence of several morpheo-climatic, lithological, and structural factors: ultramafic bedrock, tropical climate (with contrasted seasons, and levelled relief (with karstic drainage) with
The climate of Brazil is primarily tropical, with contrasting seasons. The vegetation is a dry brushland, with thorny shrubs and cacti ("caatinga"). The average temperature is 24°C to 26°C, and precipitation is below 800 mm, with 8 to 9 months of very dry season.

In the Central Brazil, the climate is hot and humid, with contrasting seasons. The vegetation consists of savannah with some trees ("cerrado" or "campo limpo"). The average temperature is between 22°C and 25°C, and the rainfall is between 1200 and 1800 mm, with only 2 to 4 months of dry season.

On the Atlantic Coast of Southeastern Brazil, the tropical climate is semi-hot and semi-humid (average temperature 20°C, and rainfall 1500 to 1900 mm). The vegetation is of the tropical forest type. In the Amazon Basin of Northern Brazil, the climate is equatorial, hot, and very humid (average temperature above 26°C, and precipitations above 1800-2000 mm). The vegetation is of the great equatorial forest.

### Table 1. Nickel deposits of Brazil.

<table>
<thead>
<tr>
<th>State</th>
<th>Name of the massif</th>
<th>Approximate size of the ultrabasic massif</th>
<th>Reserve—m (measured and estimated)</th>
<th>Content %Ni</th>
<th>Bibliographic reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minas Gerais</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sao Paulo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piauí</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahia</td>
<td></td>
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<tr>
<td>Pará</td>
<td></td>
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</tr>
</tbody>
</table>

Secondary rejuvenation after a tectonic uplift (Trescaces, 1975; Lelong et al., 1975). All these favourable conditions are not simultaneously satisfied for each Brazilian nickeliferous deposit. And each deposit shows characteristic features, according to its particular recent evolution.

### (A) Climate

The following main bio-climatic zones can be distinguished in Brazil (Romaris, 1974).

(i) In the Northeast, the climate is hot and semi-arid. The vegetation is a dry bushland, with thorny shrubs and cacti ("caatinga"). The average temperature is 24°C to 26°C, and precipitation is below 800 mm, with 8 to 9 months of very dry season.

(ii) In Central Brazil, the climate is hot and humid, with contrasting seasons. The vegetation consists of savannah with some trees ("cerrado" or "campo limpo"). The average temperature is between 22°C and 25°C, and the rainfall is between 1200 and 1800 mm, with only 2 to 4 months of dry season.

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(iv) The climate of Southern Brazil is transitional to a temperate climate. Nickel deposits occur in the first four climatic zones and mainly in the second one (tropical climate with contrasting seasons).

### (B) Relief

Most of the ultramafic massifs of Brazil comprise hills, sometimes tabular, or mountains. These elevations look down on broad levelled plains. The ultrabasic reliefs are of three types:

(i) Tabular hills and mountains. This is the most frequent topographic form. Hill tops and plateaus are capped by a hard layer of silcrete. The slightly weathered rock crops out on steep slopes.

(ii) Frequent topographic form. Hill tops and plateaus are capped by a hard layer of silcrete. The slightly weathered rock crops out on steep slopes.

(iii) On the Atlantic Coast of Southeastern Brazil, the tropical climate is semi-hot and semi-humid (average temperature 20°C, and rainfall 1500 to 1900 mm). The vegetation is of the tropical forest type. In the Amazon Basin of Northern Brazil, the climate is equatorial, hot, and very humid (average temperature above 26°C, and precipitations above 1800-2000 mm). The vegetation is of the great equatorial forest.

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A similar landscape can be presented by the ultramafic-alkaline massifs (Serra Agua Branca, GO.—Lesn Subriales et al., 1971; Justo, 1973). The large massifs show a contrast of reliefs, with highlands, foothills, and lowlands. It is possible, however, to identify the highlands as plateaus, as in the case of the Southern part of Niquelandia (Fig. 3), where the top of a hill is a relief of an old plateau with silcrete (the pyroconite bands correspond to valleys, slightly carved into the old peneplain) (Pecora and Barbosa, 1944; Pecora, 1944; Barbosa, 1968; Costa, 1970).

(ii) Plains and hills. The largest massifs show characteristic features of a dissected, old plateau; foothills and plains are dominant, with ferruginous detrital material, sometimes with iron-crust near the crests; around these low zones are some hills with steep and silcrete on their tops (Santa Fe and the Northern part of Niquelandia, Fig. 3).

(iii) Finally, some massifs have been wholly levelled by erosion, mainly in the semi-arid Northeast.

(C) Interpretation of the evolution of the relief

The suggested course of evolution of the relief is as follows:

(i) During the late Cretaceous, the uplift of South America began. A very long period of erosion established an extensive peneplain: the South American erosion surface (King, 1956). The weathering products of this cycle are lateritic (Braun, 1971), but show silica accumulation (silcrete) over ultramafic rocks (Santon, 1974; Trescases and Oliveira, 1978).

(ii) In the late Tertiary, a new erosive cycle began; the Velhas Cycle (King, 1956). A new, lower surface was formed, after incision and dismantling of the South American Surface. In the areas of ultramafic rocks, however, silcrete impeded the levelling of the relief. Thus plateaus and tabular hills with silcrete are relics of the South American Surface.

(iii) In the Quaternary, erosion has continued, restricting the hills even more. The landscapes of Niquelandia and Santa Fe are in a more advanced stage of erosion than the others. During the Quaternary, the weathering attached at the same time both:

— the reliefs of the South America Surface (Highlands), where weathering profiles are developed under the silcrete;

— and the new base level (Velhas Surface), with deep weathering profiles. This weathering is controlled by recent climate conditions.

DIFFERENT TYPES OF WEATHERING PROFILES

Weathering profiles of the highlands (Plateaus, tops of hills)

These highlands are relics of the South American Surface. Their weathering profiles were the first to begin their evolution. Several types of weathering can be distinguished according to the climate.

(a) Hot and humid tropical climate, with contrasting seasons (Go., Mg., Central Brazil) This climate is considered as the most propitious for the genesis of a thick latelitomorphic profile with nickel accumulation (Trescases, 1975). Indeed, it is in this climate zone that the biggest Brazilian deposit occurs. Most of the bedrocks are limestones and serpentines, sometimes harzburgites. Figure 4 shows some weathering profiles at Morro do Niquel (Griffon and Ribeir, 1976; Langer, 1969; Santivanez, 1965; Trescases and Oliveira, 1978). Barro Alto and Niquelandia and gives for comparison one profile on pyroxenite in Niquelandia. The profile appears really different only on Pyroxenites. On rocks rich in olivine and/or serpentines, the profiles always appear as one of the two extreme types: Morro do Niquel and Barro Alto. Two principal layers can be distinguished:

Weathered zone, with preservation of the structure of the rock.

Silicified and/or reworked top zone.

Weathered zone. The weathering of the hard, dark, dense fresh rock begins with the modification of the colour during the "slightly weathered rock stage" (R-SG in Fig. 4). The thickness of this layer is between 2 and 5 m. Next, cohesion and bulk density decrease, with thicknesses between 2 and 1.5: this is the coarse saprolite stage (SG). When cohesion disappears, the rock is transformed into a brown argillaceous mass, with conservation of the rock structure, but with very low density (under 1.2). This is the fine saprolite stage (SF) very thick (1 to 2 m) and sometimes absent. In the stratalite pyrolytic, the coarse saprolite is the thickest horizon of the weathered zone. This stage is intermediate between the slightly weathered rock and the fine saprolite. But depending on the case, it maintains some features of the former (rocky type, as at Morro do Niquel), or it quickly loses all cohesion (argillaceous type, as at Barro Alto). Some silicification can occur in the coarse saprolite as vertical veins (Barro Alto, Fig. 4) or fractures fillings.

(iii) Finally, some massifs have been wholly levelled by erosion, mainly in the semi-arid Northeast.

The garnierite is a mixture of micaespinellic nicasilicate (hydrated-talc, serpentine, montmorillonite, chlorite, serpentine, chalcedony). (Based on Tarn Linn Heng, 1972).
The coarse saprolite; next, this network is replaced by a nickeliferous goethite network (fine saprolite).

Nickeliferous silicates (mainly hydrated talc-like)

The magoesium content decreases with weathering.

The nickel content shows a strong variation from one sample to another.

Nickeliferous laterites of Brazil

Table 2. Average chemical composition of the two types of weathering profiles in the Highlands.

<table>
<thead>
<tr>
<th></th>
<th>SiO₂</th>
<th>MgO</th>
<th>Fe₂O₃*</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>NiO**</th>
<th>MgO</th>
<th>CaO</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR</td>
<td>17.0</td>
<td>2.4</td>
<td>41.5</td>
<td>5.9</td>
<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Si</td>
<td>18.5</td>
<td>2.6</td>
<td>41.5</td>
<td>5.9</td>
<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
<tr>
<td>SF</td>
<td>18.5</td>
<td>2.6</td>
<td>41.5</td>
<td>5.9</td>
<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
<tr>
<td>R-SG-SF</td>
<td>18.5</td>
<td>2.6</td>
<td>41.5</td>
<td>5.9</td>
<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
<tr>
<td>R-SG</td>
<td>18.5</td>
<td>2.6</td>
<td>41.5</td>
<td>5.9</td>
<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
<tr>
<td>R</td>
<td>18.5</td>
<td>2.6</td>
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<td>2.6</td>
<td>2.6</td>
<td>0.9</td>
<td>2.8</td>
</tr>
</tbody>
</table>

The isovolumetric balance (gain and loss) of the weathering confirms that magnesium and part of the silica are progressively leached in the weathered zone (part of the silica precipitates as amorphous compounds). Nickel shows absolute gains. The other elements are strictly constant. In the silcrete, the residual elements are again constant, but here, there is a loss of nickel and an absolute gain of silica.

The evolution of the highland profiles in a tropical climate with contrasting seasons. The evolution of the highland weathering profiles in a tropical climate with contrasting seasons comprises the progressive, but sometimes incomplete, destruction of the silicates in favour of a goethite residue; this is an evolution with a lateritic tendency.

However, some residual free silica remains; and this evolution, in the recent morpho-climatic conditions of Central Brazil, does not allow the development of thick ferruginous horizon of fine saprolite typical of the lateritic profiles of New Caledonia, for example (Treasure, 1975).

Nickeliferous laterites of Brazil

For mining, the silcrete is poor in nickel and considered barren. The "red laterite" layer contains medium grade of nickel (1% Ni) where it is not derived exclusively from the silcrete; it is an "oxidized" ore. The weathered zone represents the main part of the ore. The more complete the weathering, the higher is the grade of nickel; the best layer is at the top of the saprolite zone. This ore is a silicified rock.

(b) Semi-arid tropical climate (Bahia, Piauí, northeastern Brazil)

In spite of the abundance of ultramafic rocks in the state of Bahia, there is only a small number of nickel deposits in the Brazilian semi-arid region. This climate favours mechanical processes of erosion, rather than chemical weathering. A lot of the ultramafic masses of this zone are strongly eroded, as at Andorinha (BA), where the relief is wholly levelled. Here, the weathering profile is not thick, and shows only some smectitisation and veinlets of...
In Paraíba, Santa Catarina and Rio Grande do Sul (South of 25°S Latitude) the recent weathering is not lateritic and the profiles are not thick. Vermicu-
line and smectites are the dominant minerals and nickel concentration does not occur. Even during the Tertiary, the weathering probably was not laterit-
ic in the South.

Profiles of the plains and lowlands
(a) Tropical climate with contrasting seasons (Galápagos)
The weathering profiles observed in the low part of the massifs of Santa Fe and Nicquelônia (North-
ern part) are very similar. The weathered zone shows the same sequence of horizons present in the high-
lands: slightly weathered rock, coarse saprolite, and fine-grained ferruginous saprolite which is thicker here.

The superimposed weather zone is very different; the profiles of the lowlands never show the silcrete cover characteristic of the highlands. The upper part of the lowland profiles is always made up of about 3m (or more) of powdery red laterite, with ferro-
ginous fine gravels.

The mineralogical evolution of the profile is the same in the lowlands as that previously described in highlands. The mean chemical composition of each layer for the massif of Santa Fe is given in Table 3. The similarity between these compositions and the corresponding horizons of the highland pro-
files (Table 2) is very high, with the evident exception of the top layer of red ferruginous laterite. A part of the accumulated nickel of the lowland profiles is of residual origin; but the rest comes from the highlands either through mechanical processes with the colluvial red laterite or by chemical processes, through lateral migration.

In conclusion, in the humid tropical region of Brazil with contrasting seasons, the weathered zone

| Table 3. Average composition of each horizon in the massif of Santa Fe. |
|-------------------------|----------------|-----------------|------------------|-----------------|
|                        | Fe (%)          | MgO             | CaO              | SiO₂             |
| LR                     | 5.2             | 10.1            | 1.9              | 70.8             |
| GP                     | 9.9             | 23.9            | 9.9              | 29.0             |
| SG                     | 12.1            | 40.8            | 38.1             | 15.5             |
| R-SG                   | 12.8            | 41.0            | 33.4             | 10.4             |
| R                      | 7.4             | 26.3            | 41.1             | 13.2             |

Notes: Total Fe as Fe₂O₃ (Fe₂O₃ for the fresh rock only). Without the garnieritic veins.

LA: Red laterite.
SF: Fine saprolite = yellow laterite.
SR: Weathered rock = Coarse saprolite.
R-SG: Silted, slightly weathered rock.
R: Fresh rock.

In the lowlands the weathering is in equilibrium with recent elimination processes. The weathering evolution is more complete in the lowlands. The reserves of nickel ore are more important in the lowland profiles, where three layers constitute one ore:

--- coarse saprolite, silicated ore, with 1% Ni ---
--- red laterite, oxidised ore, with 1% Ni ---
--- fine saprolite, transitional between silicated and oxidised type, with content of Ni (1 to 4%), but with restricted thickness.

(b) Semi-arid tropical climate (Piauí)
A foot-hill region is developed around the central plateau of the Serra do Piauí massif. These foot-
hills are connected with the "Velloso" plain. Figure 5 shows the schematic disposition of the horizons for all the topographic sequence slope-foot-hill-plain.

The colluvial surface horizon contains a lot of crumbled blocks of silcrete within a powdery browned material. Exclusively on the topographic knick point, these blocks have a ferruginous cortex, and are cemented by iron hydroxides (iron crust appearance).

The weathered zone shows a saprolitic horizon (argillaceous type in the plain; rocky type on the slope and at the bottom of the profile). On the lower part of the slope, this saprolite is silicified. On the slope, only slightly weathered rock crops out.

The mineralogical evolution is the same as that described for the plateau: transformation of the ser-
pentine into smectite, mainly in the foothills and on the plain; incipient formation of goethite at the surface; predominance of quartz and chaledony in all the colluvial cover and in the coarse saprolite in the lower part of the slope.

The chemical evolution is marked by the preserva-
tion of iron and silica (and even by the introduction of silica coming from topographically higher silcretes). The magnesium is quickly leached as soon as the serpentine disappears. The nickel migrates laterally from the plateau to the plain through the weathered zone. Without this contribution, the leach-
ing of the magnesium alone could not produce a significant relative concentration of the residual nick-
el in the rock. The colluvial cover is barren (0.2 to 0.3% Ni). The coarse saprolite is nickel ore: 0.8 to 1% Ni (with locally 3% Ni) in the rocky type and 1.2 to 1.5% Ni in the argillaceous type.

GENETIC INTERPRETATION

Beluga is a tropical country with numerous ultrama-

LATERITISATION PROCESSES

The small occurrences of Serra das Marcecas, in Cerro do Paiva, Bahia, and Maringaçu (Pará) are dis-

--- The common features of the Brazilian deposits, and also the differences between the deposits found in different bio-climatic zones, are in accord with the following interpretation of the successive stages of their evolution (Fig. 6).

(i) The redistribution of elements began in the Early Tertiary, with the South American levelling cycle. In already levelled relief, a semi-arid climatic period induced the formation of a silicified layer at the bottom of the weathering profiles on ultramatic rocks.

(ii) Later, a more humid climate promoted the laterisation of these paleo-profiles, and a prelimi-

nary (residual) concentration of nickel. However, to the south of 25°S latitude, silicification and laterisation seem not to have occurred.
In the Late Tertiary, with the breaking up of the South American Surface, the latitudinal weathering fronts were removed, and the silicate exposed. With this protection against erosion, the ultramafic massifs appeared little by little as plateaus above the levelled “Velas” Surface.

During the “Velas” cycle, weathering was active beneath the silicate which covers the plateaus (South American reliefs), and in the “Velas” lowlands. In accordance with recent climatic conditions this weathering shows a lateritic tendency in Central Brazil (tropical climate with contrasting seasons).

With the progress of erosion, the South American reliefs disappear. The nickel is progressively transferred from the highlands towards the lowlands, where it enriches the new-formed weathering profiles.

CONCLUSION

The main features of the Brazilian deposits are:

(i) genesis correlated with two levelling cycles in the Early and Late Tertiary.

(ii) Because the lateritic tendency is high at the bottom of the weathered zone (2-5%), the Holocene coarse saprolite is also nickel ore (1-25%). The best deposits are located in the highlands.

(iii) Important silicification on the highlands.

(iv) Lateritisation more advanced in the lowlands.

(v) With the progress of erosion, the South American massifs appeared little by little as plateaus above the silcrete which covers the plateaus beneath the silcrete which covers the plateaus.

(vi) Preferential accumulation of nickel in the lowlands.

(vii) Some small deposits of the Southern Hemisphere show similarities with the Brazilian type. In South Africa (De Wael, 1971) and in Australia silicification in the highlands and lateritisation in the lowlands have been mentioned. In these profiles the nickel content increases toward the upper part.

This differentiated superelevation evolution of the ultramafic rocks of the two hemispheres could result from world climatic variations correlated with the movement of the poles and the continental drift during the Tertiary and Quaternary.

ACKNOWLEDGMENTS

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This publication represents a condensed paper extracted from a more complete work to be published in Cahier ORSTOM Minéral. We thank ORSTOM for the authorization to reproduce the figures of the main work.

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LATERITIZATION PROCESSES

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THE LATERITIC FORMATIONS IN USSR

The contemporary climatic conditions in USSR is such that on its territory the lateritic formations do not occur. We are aware only of the fossil lateritic formations associated with earlier weathering epochs. They are formed in the weathering zone due to the accumulation of iron and aluminium oxides with some other elements following the leaching of silicon, alkaline earth metals and of other soluble components in the course of the weathering of parent rocks of silicious or silicic compositions.

Among the lateritic formations of USSR we may mention the following: iron ores of residual origin (laterite) and lateritic bauxites. The former, in turn, are subdivided into: (1) iron ores rich in haematite and magnetite which were formed due to the jaspilite weathering, and (2) iron ores of hydrogoethite composition—goethite forming the upper crust of the weathering mantle on serpentinites.

The study of weathering layers, and their metalliferous deposits, phlegrography, mineralogy and geochemistry (IGEM), carried out at the Geologic Institute of the Academy of Sciences in USSR, has established existence of some zonation in the structure of the alteration layer (I.I. Guinzaixburg et al., 1946; A.P. Nikitina et al., 1968). In particular, on the weathering layer of the serpentinites, we can distinguish few zones characterised by their mineralogical composition. The following are these zones from below upwards: (1) Zone of serpentinites, slightly weathered and lixiviated; (2) zone of montmorillonitised serpentinites; (3) Zone of nontronitised serpentinites; and (4) Zone of kerolithised serpentinites. The weathered bed of serpentinites is studied in detail at the Urals range where its age is determined to be upper Mesozoic era. Normally, the thickness of the weathering bed, which has a large lateral extent, varies from 10 to 40 m. In a few areas of ultramafic rocks from the Southern Urals range (those of Kamskii, Khalilovskii and others), mainly consisting of apoperidotic serpentine, a clear zonal structure is noticed. (1) The lowest zone consists of disintegrated rocks favourably passing downwards into serpentinites. According to I.V. Vitovskia (1976) the disti-
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