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WEATHERING OF THE NEW-CALEDONIAN ULTRAMAFIC ROCKS AND CONSECUTIVE SEDIMENTATION

by

Frédéric J. BALTZER (Conference Delegate)
Jean Hugues GUILLON
Jean Jacques TRESCASES

Geologists - ORSTOM - Nouméa.

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The "Office de la Recherche Scientifique et Technique Outre Mer" (O.R.S.T.O.M.) undertook in 1965 a study directed by Professeur P. ROUTHIER (Paris) concerning the weathering of the New-Caledonian ultramafic rocks and the resulting sedimentation.

Let us give an abstract of the New-Caledonian Geological history -

- Since Permian to Lias, marine sedimentation produces greywackes
- During Jurassic occurs a first orogenic phase, followed by upper Jurassic conglomerates and schists
- During Cretaceous, detritic sedimentation produces coal bearing bulks.
- Eocene deposits are phtanits and flysch, followed by large submarine basaltic or andesitic lava flows.
- A second orogenic phase follows this magnatic flow.Eocene and ante-eocene rocks are folded and submitted to general metamorphism. (mainly in the North-East of the island).
- A thick ultramafic rock blade appears during oligocene, after this folding phase.
- Miocene limestone deposits.

One third of New-Caledonia consists of an ultramafic complex whose weathering began at the end of the Tertiary Era, producing very important ferrallitic bulks. A large barrier reef around the island isolates from the oceanic basin a shallow lagoon which retains the byproducts of weathering driven to the sea by rivers.

Our programme includes the study of some sound peridotites, of their weathering and, eventually, of the sedimentation of the products transported by running waters wether in suspension or in solution. We shall therefore deal with the study of a river basin covering an ultramafic rock area as large as possible, the related coastal plains and marshes and the sediments of the lagoon itself.

The first step was to choose a suitable river basin. It had to lay only over peridotites and had to be large enough to fit with precise hydrological study. Moreover, high summits and large ferrallitic areas were essential to our purpose. Eventually, the Dumbea river drainage basin, close to Noumea, was choosen.

In future the programme will be extended to other river basins in order to give a general view of rock wasting and consecutive sedimentation in New-Caledonia.

Field works include :

- The river basin petrography, with mineralogy and geochemistry of sound rocks by J.H. Guillon.

- Weathering profiles mineralogy, and geochemistry underground and surface running waters geochemistry by J.J.Trescases.
- Sedimentology, geochemistry, hydrology of coastal plains, seashore marshes and lagoon borders by F. Baltzer.
- When our team is complete, other men will deal with lagoon problems.

THE RIVER BASIN PETROGRAPHY

New-Caledonian ultramafic rocks cover 6000 km2. They have been studied by a great many geologists since the end of the 19th century. French ORSTOM expedition (Arnould, Avias, Routhier), beginning 1946, gave evidence that peridotites occur either as laccoliths and sills interbedded in different formations, or as large covering bulks like the southern peridotites of New-Caledonia. In this case, the ultramafic body covers folded eocene flysch and eocene basaltic lava flows. Sometimes, a large blade of secondary silica separates basalts from upperlying peridotites.

The origin of peridotites is much debated. P. Routhier supports the magmatic theory considering peridotites as a result of a large submarine intrusion occuring late after the tertiary orogeny. J. Avias upholds a metasomatic theory according to which peridotites would result from underlying basalts metamorphism. Of course, this theory needs some elements migrations, especially of magnesium.

Petrographic datas

Since the research work done by Lacroix (1942), we know that many rocks of different composition and structure constitute this magnatic body. Routhier, Avias and Arnould confirmed that the ultramafic complex of New-Caledonia is not an undifferenciated one. So, there are various types of ultramafic rocks which are all grained holomelanocrat rocks : chromiferous dunite (olivine only), Harzburgite (olivine + orthopyroxene), wehrlite (olivine + monoclinic pyroxene), pyroxenolites (monoclinic pyroxene alone) as well as some rocks of mean basicity : Ouenite (olivine bearing gabbro), allivalite (olivine + plagioclase), norite (hypersthene, disthene, plagioclase), euphotide (plagioclase, diallage) and plagioclasolite.

New field surveys indicated that these basic rocks are more common than was expected.

Geological abstract

The New-Caledonian ultramafic body appears as a thick blade (about 2 km in thickness) slightly folded and more or less parted. Its basement contact is a very neat one. There is a magmatic bedding shown by the length and layering of pyroxene crystals (in harzburgites and wehrlites) and by successive layers (the width of which may be from 1 cm to several meters) wholly made either of olivine or of pyroxene. A post intrusive ~~gravitational~~ differenciation seems necessary ~~is needed~~ to explain this ordering within the magmatic stock, mainly for the most basic rocks. Petrographical and geological data, in the present state of knowledge, firmly suggest an ultramafic volcanism.

Strongly weathered basic rocks (of the kin of gabbro) are mainly found in basins in the middle of the southern peridotic mass : for instance "Vallée des Pirogues, Montagne des Sources".

The border between ultrabasic and basic rocks is sometimes clear cut, but this does not prove that there is no relation between theese rocks. Basic rocks result possibly from the last phase of differenciation inside the ultrabasic magma.

We intend first to find an answer to that problem through field and laboratory work (mineralogy, petrofabric), then to study the behaviour of elements (mainly metallic ones) included in these sound rocks and eventually geochronology and palaeomagnetism.

This study will first be carried out in the Dumbea river basin, then we shall extend our field programme in order to get a large amount of datas relative to the whole southern peridotic mass, which will enable us to get a better understanding of theese problems.

WEATHERING AND TRANSPORTATION

Behaviour of the elements during Weathering

Peridotites are mainly harzburgites with olivine and enstatite. Silicium and magnesium are 80 percent of the rock. The elements dissolve during the decay of weathered silicates and pass into ground water.

- Silica precipitates as opale at the lower part of profiles. It also precipitates along the border surface of peridotites against other rocks, thus building up a quartz wall 50 to 100 meters wide Lastly, river-waters flowing down peridotites areas contain silica.

- Magnesium deposits are giobertite at the bottom of mountains. A fair amount of magnesium is found in running waters.

- Nickel highest occurence affects the parent material giving proof that it migrates down the weathering profile where it is eventually locked inside antigorite crystals.

- Other elements, Iron, Cobalt, Chromium, concentrate in the upper part of profiles.

Lateritisation, or ferrallitisation ($\frac{SiO_2}{Al_2O_3} < 2$) occured during. Miocene and since then, the related peneplain is now found several hundred meters above sea level. Following erosion drove to the sea the by-products of weathering in suspension in rivers mainly during heavy tropical rains accompanying cyclones.

Field work

1) It includes mainly a survey of the ferrallitic sheets over the Dumbea river basin - Several soil types are under study :

   - Strongly ferrallitic soils (Acrox), over slight slopes or peneplains, with in situ developped ironstone.

Such profile is :

Humiferous A, not very thick and poorly humic

Accumulation B :

B_1 red to purple brown
from silt to gravels or ironston when uncovered

B_2 yellow brown - clay to silt sized

B_3 yellow - Porous

C Yellowish weathered parent material.

Possible variations :

- Strongly ferrallitic soil, over slight slopes, covered with ironstone debris and transported shringles.
- Ferrallitic soil over slight slopes without shringle B zone.
- Ferrallitic slope soil, eroded, giving a profile shortened to any of the zones of the theoretical profile.
- Slope soils = Red-Brown, poorly mature, iron and magnesium rich. It gives such profiles as AC or A(B)C. (B) means that B is almost unsignificant. Unmature soils weathering being slower than erosion.

2) Behaviour of the elements along the weathered profiles.

Major studies will be the following = Chemical analysis of major elements, spectrographical analysis oftrace elements, mineralogical analysis : Xray diffraction, DTA, thermogravimetry.

3) Sampling and analysis of ground water inside profiles.

Only physics and chemistry of ground waters can enable us to give interpretation of weathered rocks and soil profile analysis. This work will be done in situ as often as possible. It includes pH, Eh, resistivity, temperature measurements and sampling for laboratory work.

4) Sampling and analysis of running waters and of their possible mineral transported by products.

Dumbea river basin being harnessed for a sound hydrological study (totalizing rain-gange, shower recorder, level and evaporation measuring devices). The result of it should allow a kind of balance-sheet of the behaviour of the elements during weathering.

Some examples :

As an example, Dumbea river water transports in solution :

Ca^{++}	0	ppm
Mg^{++}	11,4	ppm
Cl^-	6,8	ppm
HCO_3^-	56	ppm
SiO_2	14	ppm

Its pH is 7,5

Yaté river, during a cyclone, gave the following water sample =

Mg^{++}	0.6	ppm
Cl^-	2.4	ppm
SiO_2	1	ppm

This river basin flows over rocks which are quite similar to that of previous one. It is obvious that water sampled during a cyclone have much less elements in solution. But it contains a lot of elements in suspension (226 ppm) :

Suspension analysis :

SiO_2	2.90	%
Fe_2O_3	57	%
Al_2O_3	9	%
MgO	0.80	%
Cr_2O_3	2.10	%
MnO_2	1	%
NiO	1.15	%

SEDIMENTATION

Field work

The byproducts of weathering give way to a twofold problem due to ancient deposits and present ones.

The ancient quaternary debris are nowadays included in terraces. They will be studied in a thorough stratigraphical survey. Geomorphology will help to see the correspondence with wave cut terraces. Both of these studies will enable us to describe the related ancient climates through the informations given by clay minerals, carbonate crusts, gypsum, fauna, etc. The corresponding movements of sea level during quaternary will also be considered.

The areas where sedimentation is occuring to day will be methodically sampled by corings and bottom samplings. It concerns mainly the lower course of rivers and the lagoon. A specially designed two-hulled boat will be used.

Some previous datas

Coral reefs and mangrove swamps which are excellent landmarks of ancient sea level kept by sediments are found in the areas where we are working. During the New-Caledonian Coral Reefs french expedition, I had an opportunity to study an example of a very recent marine transgression.

New-Caledonian coasts are bordered with swamps. For the time being they show a vegetal zoning from the seashore to the mainland.

There are several belts with growths of Rhizophora mucronata, Avicennia officinalis, Salicornia australis, and a dried up algal stuff. Close to the mainland appears a narrow area without any vegetation at all.

A stratigraphic survey of one of theese swamps showed at the bottom a blue-green montmorillonite mixed with coral shringles, lying over a buried coral reef. A probably flandrian transgression appears as a mangrove peat. It is covered with a shelly mud which is brownish against the peat and whitish elsewhere.

It is possible to follow the transgressive peat bed from the bottom to the summit of the series, along the slight slope of the montmorillonite bed. A stand still of sea level corresponding to the Rottnest terrace described by Fairbridge gave way to the formation of a second mangrove peat bed when the sea level was at its highest. This upper peat bed is related to the lower one at the margins of the swamp, giving a very good example of facies obliquity in regard to chronology.

Recent peat is covered with kaolino-illitic clay which sedimented in very shallow water except where peat constitutes the living mangrove soil.

A regression following Rottnest terrace high sea level dried up the kaolino-illitic clay and drew down the mangrove trees to their present position. Some physiographic datas show a present transgressive tendency. Gypsum and iron oxydes are found at the bottom of the thin kaolino-illitic layer, near the borders of the swamp. A chemical and mineralogical study indicated an oblique concentration of underground salt water near the mainland. Evaporated water is replaced by sea water through the sediments.

Eh and pH conditions, due to mangrove organic matter fermentation, increase iron solubility in the living mangrove soil and iron deposits at the margins of the swamp, in the dry area, at the top of the water table.

These mechanisms will be studied once more during the present research work and other ones will be searched in order to give a more complete description of the sedimentation of weathered peridotides debris. It will increase our knowledge of the elements behaviour.

Laboratory work

Both ancient and modern sediments will be submitted to mineralogical analysis by X rays, D.T.A. and thermogravimetry, to chemical analysis of major and trace elements and to radiocarbon chronology. All simple analysis will be secured in Noumea.

HYDROLOGY

To understand the way elements are transported, we need specific informations about sea water as well as about underground and river waters.

Physical and chemical investigations will be carried out. The first ones will be secured aboard the boat, chemistry will need the amenities of a land laboratory.

FINAL AIM

This work will enable us to know the position of the elements inside the sound rocks and their behaviour during weathering, transportation and sedimentation. We shall try to describe as accurately as possible the various stages of several important metals during their journey from the peak of mountains to the bottom of the lagoon.

Such a programme is not unique in the world as a similar one is carried out by ORSTOM in Ivory Coast and Tchad.