

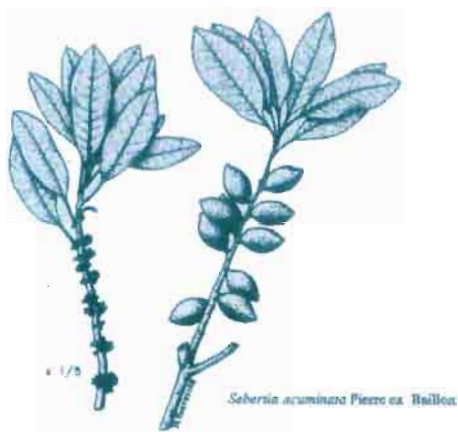
DEUXIÈME CONFÉRENCE INTERNATIONALE SUR L'ÉCOLOGIE  
DES MILIEUX SERPENTINIQUES

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RÉSUMÉS  
ABSTRACTS



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**COMMUNICATIONS ORALES**

**ABSTRACTS**

**ORAL COMMUNICATIONS**



## PREMIERS RÉSULTATS SUR LES ENDOMYCORHIZES DES PLANTES DE MAQUIS MINIERS

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Les mycorhizes, champignons symbiotes des végétaux, jouent généralement un rôle important dans l'adaptation et le développement des plantes sur sol peu fertile. En Nouvelle-Calédonie, aucun travail de recherche n'avait été réalisé, sur la mycorhization des espèces de maquis miniers. Les premiers résultats font ressortir l'intérêt des mycorhizes dans l'optique d'une revégétalisation des sites miniers dégradés.

Une quinzaine d'espèces végétales appartenant à des familles très diverses (Protéacées, Cypéracées, Rhamnacées, Euphorbiacées, Myrtacées, Casuarinacées), ont été étudiées sur 3 types de sols : sol brun hypermagnésien, sol ferrallitique oxydique à grenaille, sol ferrallitique colluvial. La grande majorité de ces plantes sont mycorhizées, les endomycorhizes à arbuscules étant les plus fréquemment observées. Parmi les Cypéracées, famille comportant des plantes habituellement non mycorhizées, le genre *Costularia* semble faire exception, puisque les 2 espèces observées, sur 3 sols différents, sont infectées par des endomycorhizes à arbuscules. Sur le plan qualitatif, les MA sont classiques et comportent des vésicules fréquentes et une quantité d'arbuscules très variable d'une racine à une autre, d'une plante à une autre. Le taux de mycorhization, varie généralement entre 10% et 90%. Cette mycorhization relativement importante, est à relier notamment à la grande pauvreté en phosphore des sols étudiés.

En ce qui concerne, le potentiel mycorhizogène, les sols sont caractérisés par des densités en spores mycorhiziennes différentes :

- 2900 à 6100 spores/100g de sol sec pour le sol brun hypermagnésien
- 470 à 1700 spores/100g de sol sec pour le sol oxydique à grenaille
- 670 à 1600 spores/100g de sol sec pour le sol ferrallitique colluvial.
- absence de spores pour une latérite et une saprolite prélevées dans une ancienne mine ce qui rend l'apport de substrat ou de plantes mycorhizés indispensables pour la revégétalisation des sites miniers.

Les premières descriptions des spores semblent indiquer que les genres endomycorhiziens les plus représentés sont *Acaulospora* et *Glomus*.

Les travaux en cours visent à quantifier plus précisément l'apport de ces champignons aux plantes des sols miniers, à isoler, déterminer et sélectionner les souches les plus efficaces et à étudier leur résistance aux métaux.

## **INFLUENCE DE QUELQUES MÉTAUX SUR LA CROISSANCE ET LA GERMINATION DE SOUCHES FONGIQUES ISSUES DE SOLS MINIERES**

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Les sols des maquis miniers néo-calédoniens sont caractérisés par de fortes teneurs en certains métaux, en particulier : fer, magnésium, manganèse, nickel, chrome et cobalt. L'activité microbienne directement liée à la fertilité est ainsi limitée par la toxicité métallique. La densité microbienne y est de 50 à 10.000 fois plus faible que dans des sols agricoles de fertilité moyenne. Cependant, il est probable qu'une microflore adaptée à ces conditions difficiles se soit développée dans ces sols. Il importe, dans un premier temps, de vérifier l'existence d'une telle adaptation.

Deux lots d'une quinzaine de champignons sont constitués : un lot de souches issues de sols miniers et un lot de souches issues de sols agricoles contenant très peu de métaux, afin de les comparer.

Les résultats font ressortir les conclusions suivantes :

- Parmi les champignons issus de sols miniers, un certain nombre de souches montrent une croissance très lente, même sur des milieux riches. Cette caractéristique rappelle la lenteur de croissance des plantes qui poussent sur ces mêmes sols.

- Les souches issues de sols miniers se caractérisent par la résistance à au moins un métal sur les 5 testés, ce que nous ne notons pas chez les souches issues de sols agricoles, généralement sensibles à tous les métaux. Pourquoi, une résistance à un seul métal, dans un milieu qui contient plusieurs ? L'hypothèse que nous tenterons de vérifier est que le sol est hétérogène, qu'il comporte différents microsites dans lesquels un métal, différent selon les sites, peut être en forte concentration tandis que les autres sont moins concentrés. Des données précises sur les concentrations en métaux solubilisés dans les sols étudiés sont aussi nécessaires pour répondre à cette question, les données existantes étant insuffisantes.

- En ce qui concerne la germination des spores fongiques, il apparaît que les souches de sols miniers sont généralement plus résistantes aux différents métaux que les souches de sols agricoles.

L'ensemble des résultats semble bien indiquer l'existence d'une adaptation particulière à la toxicité métallique des champignons des sols de maquis miniers. Cependant, la faible croissance de beaucoup de souches pourrait indiquer une activité générale plus faible que les souches de sols classiques, ce qui serait limitant pour la fertilité.

## NICKEL UPTAKE AND NUTRITION OF *BERKHEYA CODDII* GROWING ON SERPENTINE SOILS IN SOUTH AFRICA

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*Berkheya coddii* is a herbaceous perennial that is endemic to the serpentine soils of the south eastern Transvaal (South Africa), particularly near the Agnes Gold Mine and the Queen's River syncline in Barberton.

In 1989 Morrey *et al* reported that *B. coddii*, growing at the former site, was able to hyperaccumulate nickel up to 13 900 mg per kg dry leaf material, a finding that encouraged us to further investigate this plant. In this paper, we will present composition and distribution data for nickel and other heavy metals within *B. coddii*, as well as evidence for the path and rate of nickel uptake by the plant, and the nutrient requirements for optimal growth and nickel uptake. We will also discuss the implications of employing this plant for the detoxification of industrial waste, the mining of metals and the improvement of the environment.

Morrey, D.R. Balkwill, K. & Bakwill, M.J.(1989) S. Afr. J. Bot.155, 171-177

## NICKEL-ZINC INTERACTIONS IN METAL UPTAKE, ACCUMULATION AND TOLERANCE BY HYPERACCUMULATOR PLANTS

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Very few metal hyperaccumulator plants occur on both ultramafic (nickeliferous) and calamine (zinc-enriched) soils. In northwestern and southern Europe *Thaspi caerulescens* (Brassicaceae) has geographically isolated serpentine, calamine and montane (non metallophyte) populations. Analysis of leaf samples collected from field specimens and herbarium materials suggests that the species can behave both as a zinc and a nickel hyperaccumulator, and that there may be a competitive interaction in the uptake of the two metals. Similar conclusions emerge from studies of *Dichapetalum gelonioides* (Dichapetalaceae) subspecies complex from S.E. Asia.

We report the results of an experimental study of nickel and zinc uptake and tolerance by populations of *T. caerulescens* from diverse edaphic conditions, when grown hydroponically in metal-amended cultures. The experiments confirm a constitutive hyperaccumulation of zinc and indicate a strong interaction of zinc and nickel in shoot metal accumulation. Our data further suggest that metal accumulation and tolerance in *T. caerulescens* are independent characteristics.

## DIVERSITY AND CONSERVATION OF SERPENTINE SITES IN SOUTHERN EASTERN TRANSSVAAL, SOUTH AFRICA

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Major outcrops of serpentine in South Africa occur in two major areas. In the area near Barberton, Eastern Transvaal, known as the Greenstone Belt, geologists have identified and mapped 32 sites. We consider another four small sites to be serpentiniferous due to the presence of *Berkheya coddii* Roesl., a nickel hyperaccumulator. These sites show great diversity in habitat, soil characteristics and in species composition. The sites show a range in altitude from 354 to 1648 m above mean sea level ; in size from approximately 0,75 to 14,5 km<sup>2</sup>, in soil pH from 5 to 6.9 ; in total nickel from 682 to 4224 mg/kg ; in total chromium from 163 to 7329 mg/kg; in plant available nickel from 85 to 314 mg /kg and in magnesium to calcium ratio from 3 to 23.5. The sites occur in four different veld types. Investigations so far have concentrated on three sites, but based on all sites visted, 522 tolerant taxa, 13 endemic taxa and 4 hyperaccumulating taxa have been recorded. 201 taxa have been recorded at Agnes Mine, 169 at Kaapsehoop and 209 at Josefsdal and a total of 315 on all three. Data from eighteen 6 x 6 m plots at each of these three sites and a species:area curve have facilitated estimates of the number of species that would be present on sites of different sizes and thus comparison between sites and with the flora on the Great Dyke in Zimbabwe. Of the thirty six sites, four, all at similar altitude, and a small portion of another are protected in a game reserve, while a small portion of another is partially protected in this same reserve. Two very small portions of Agnes Mine (Pioneer) are protected in reserves, and Kaapsehoop and Queen's River Valley (Sawmill) are on land owned by a Government Forestry Department and have been partially planted to pine. All other sites are unprotected and some are partially disturbed by mining and prospecting operations.



## THE EFFECT OF SERPENTINE ON VEGETATION STRUCTURE, SPECIES DIVERSITY AND ENDEMISM IN CENTRAL QUEENSLAND

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Soil nutrient status varies with profile development in a range of serpentine soils in the Rockhampton-Marlborough area of Central Queensland, Australia. Soil nutrient stress affects the annual growth of foliage shoots (and insect damage to the edges of developing leaves) and ultimately the mean height of the dominant trees in the *Eucalyptus* open-forest of the area. Foliage Projective Cover of the overstorey is reduced, thus allowing more light to penetrate to the understorey which shows a concomitant increase in both Foliage Projective Cover and biodiversity (number of species per hectare).

Eleven serpentine endemics have been found in Central Queensland. At least one of the two overstorey species of *Eucalyptus*, *E. xanthope* is endemic on the serpentine, the other, *E. fibrosa*, may eventually be shown to be a serpentine subspecies of this widespread species. The Cycadales, *Cycas ophiolitica* and *Macrozamia* sp. may be common on serpentine hillsides, whereas other endemics appear on lower slopes and drainage channels where serpentine colluvium accumulates.

## MOBILITÉ DU NICKEL DANS UNE TOPOSÉQUENCE DE SOLS FERRALLITIQUES FERRITIQUES DU SUD DE LA NOUVELLE-CALÉDONIE.

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Les massifs de péridotites du Sud de Nouvelle-Calédonie ont donné naissance à des sols oxydiques très évolués : les sols ferrallitiques ferritiques ou ferrallisol. Ceux-ci contiennent des teneurs très élevées en nickel (environ 1 % de NiO). Des phénomènes de toxicité, liés à la présence de ce métal, sont à craindre lors de leur mise en valeur agricole. Une étude visant à évaluer la disponibilité du nickel dans ces sols a donc été réalisée sur une toposéquence comprenant trois des principaux faciès de sols utilisables pour l'agriculture, les sols de piedmonts, de glacis colluvio-alluvial et de terrasses alluvio-colluviales.

Dans un premier temps, des extractions chimiques par KCl 1M et DTPA 0,05M + CaCl<sub>2</sub> 0,01M à pH 5,3 ont été effectuées sur les différents échantillons de sol de la toposéquence afin de déterminer les quantités de nickel échangeable (Ni KCl) et adsorbé (Ni DTPA) par la phase organo-minérale du sol et de les comparer avec le nickel total extrait par une attaque triacide. Dans un second temps, la présence de formes solubles de nickel dans le sol est étudiée grâce à l'analyse de solutions du sol, prélevées par des céramiques poreuses, et à l'utilisation de résines échangeuses d'ions.

Les résultats montrent que pour des teneurs similaires en nickel total (environ 1 % de NiO), les teneurs en Ni KCl et Ni DTPA sont très faibles sur piedmont, respectivement de 0 à 2 µg g<sup>-1</sup> et 0 à 8 µg g<sup>-1</sup> de sol, alors qu'elles peuvent atteindre 120 µg g<sup>-1</sup> de sol dans les horizons de surface des faciès alluvio-colluviaux. L'analyse des eaux et des résines échangeuses d'ions est en cours.

L'accumulation de nickel extractible par KCl et DTPA dans l'horizon de surface de la zone alluvio-colluviale montre le rôle important joué par la matière organique, plus abondante dans ce faciès de sol. Toutefois le nickel est lié initialement à la phase minérale. Trois mécanismes peuvent agir conjointement pour expliquer sa plus grande mobilité dans les faciès alluvio-colluviaux : i) l'existence de matériaux plus riches en goethite, cette dernière ayant généralement une teneur plus élevée en nickel et étant plus réactive du fait de sa plus grande surface spécifique ; ii) l'existence d'un engorgement temporaire, de plus en plus accentué vers le bas de la toposéquence, pouvant induire la réduction des oxy-hydroxydes de fer ; iii) la présence de minéraux silicatés susceptibles de libérer du nickel. Dans ce dernier faciès, le prélèvement par les plantes du nickel qui a été solubilisé, puis son retour au sol sous forme de litière, conduit à son accumulation dans les horizons humifères. Cette accumulation de nickel facilement biodisponible pourrait induire des problèmes de toxicité sur des plantes non adaptées à ces milieux.

## **FACTEURS DE LA FERTILITÉ ET CONDITIONS DE MISE EN VALEUR DES SOLS FERRALLITIQUES FERRITIQUES DU SUD DE LA GRANDE TERRE : PROBLÉMATIQUE DE LEUR ÉTUDE**

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Les massifs de roches ultramafiques de Nouvelle-Calédonie, qui recouvrent encore 30% de la surface du Territoire, influencent plus de 40% des sols. Ceux développés directement à partir des roches ultramafiques appartiennent à la catégorie des sols ferrallitiques ferritiques, appelés aussi sols oxydiques ferritiques. L'importance du massif ultramafique du sud de la Grande Terre, sa proximité de la capitale, Nouméa, son absence de peuplement et la pluviosité du secteur - plus de 1800mm - ont attiré très tôt maraîchers, pépiniéristes et horticulteurs en quête de terrains. Ces agriculteurs se sont alors aussitôt heurtés aux très nombreux problèmes d'ordre agropédologique affectant ce type de sols, mal connus au demeurant du point de vue agronomique. Ces difficultés conduisirent la Province Sud et l'ORSTOM à associer leurs moyens, en 1991, pour étudier de façon très méthodique les facteurs de leur fertilité et les conditions de leur mise en valeur. La présente note rend compte de la problématique de cette étude, telle qu'elle a été définie initialement, et de son évolution progressive avec l'amélioration des connaissances. Les résultats détaillés d'un certain nombre des recherches entreprises dans ce cadre sont présentés, par ailleurs, par les membres de l'équipe du Laboratoire d'Agropédologie affectés à ces recherches.

## **ÉVALUATION DE LA COMPACTITÉ DES SOLS FERRALLITIQUES FERRITIQUES DE NOUVELLE-CALÉDONIE - RELATION AVEC L'ENRACINEMENT.**

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Les sols ferrallitiques ferritiques (Ferrallisol) de Nouvelle-Calédonie, développés sur les roches ultramafiques, sont connus pour leur très faible fertilité chimique et pour les problèmes que cela pose lors de leur mise en valeur agricole. Toutefois, les diverses études cartographiques menées sur ces sols ont montré l'existence d'horizons relativement compacts pouvant gêner la pénétration racinaire. Nous avons donc entrepris une étude visant à analyser les relations entre la compacité, estimée de deux façons, d'une part par la mesure de la porosité et d'autre part par des mesures pénétrométriques, et l'enracinement. Ce travail a été réalisé sur une toposéquence sous végétation naturelle comprenant deux des principaux faciès de sols utilisables pour l'agriculture, les sols de piedmonts et les sols de glacis colluvio-alluvial. Les résultats obtenus semblent montrer une bonne concordance des deux méthodes de mesure de la compacité du sol. Un seuil pénétrométrique, de  $6,29 \text{ kg / cm}^2$  (ou 20 mm), semble indiquer la limite à partir de laquelle les racines de la végétation naturelle ne peuvent plus pénétrer dans le sol. Les horizons concernés sont les horizons de profondeur (au-delà de 20 cm) sur piedmont. Les horizons de glacis sont situés en dessous de cette limite. Il n'a pas été possible de dégager une relation précise entre les données pénétrométriques et la texture du sol bien que les valeurs les plus fortes correspondent à des horizons dont la teneur en limons est toujours située au-delà de 50 %. Ces résultats ne nous permettent cependant pas, pour le moment, de savoir si la compacité est, en soit, un facteur limitant de l'enracinement ou si la fertilité chimique, extrêmement réduite de ces horizons, empêche toute possibilité de colonisation racinaire et donc toute amélioration de la fertilité physique.

## THE SIGNIFICANCE OF METAL HYPERACCUMULATION FOR BIOTIC INTERACTIONS

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Metal hyperaccumulating plants contain very high metal contents. Because of the general toxicity of metals, hyperaccumulating plants probably interact with other organisms very differently than plants containing less of these metals. We have shown that hyperaccumulated Ni deters herbivores and pathogens. Experiments using caterpillars of the generalist folivores *Pieris rapae* and *Spodoptera exigua*, and the Ni hyperaccumulators *Streptanthus polygaloides* and *Thlaspi montanum* var. *montanum*, have demonstrated the acute toxicity of hyperaccumulated Ni. The bacterial pathogen *Xanthomonas campestris* pv *campestris* and the powdery mildew *Erysiphe polygoni* were both significantly inhibited by hyperaccumulated Ni in *Streptanthus polygaloides*.

However, some organisms can circumvent these elemental defenses. Experiments with aphids (*Acyrthosiphon pisum*) showed them to be unaffected by hyperaccumulated nickel. Thus, herbivores specializing on specific portions of hyperaccumulating plants (in this case, the phloem fluid) can avoid the toxic effects seen for unspecialized folivores. We further predict that some herbivore species in areas with large concentrations of Ni hyperaccumulators (such as New Caledonia) have evolved metal tolerance, and suggest that in some cases the resulting high metal levels in herbivores will serve to defend them against predators.

Mutualist biotic interactions also are probably affected by the elevated metal contents of hyperaccumulating species. Pollination and seed dispersal mechanisms may require biotic vectors. Hyperaccumulating plants may have solved this dilemma in two ways. First, they may rely on abiotic vectors for pollen or seeds. Alternatively, they may rely on biotic vectors that are adapted to tolerate high levels of metals.

## THE ESTABLISHMENT OF VEGETATION ON MINE WASTES

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A vegetation cover is the most economical method of stabilising mine wastes and reducing pollution. It can also allow the restoration of the original plant and animal communities and therefore help in maintaining biodiversity.

There can however be problems in establishing vegetation because of toxicity from residual heavy metals, extreme physical conditions, and lack of plant nutrients. How serious these are depends on the method of mining and the nature of the waste or overburden. If original soils can be reinstated, these problems will be minimal. Otherwise each has to be dealt with.

*Toxicity.* Where this is severe it will be essential to isolate the surface by a layer of inert capping material. Alternatively it may be possible to find and develop tolerant material from local populations of selected species.

*Physical.* Extreme conditions can be overcome in a number of ways, such as protective fences, surface mulches, appropriate surface cultivations, and nurse species.

*Nutrients.* The major nutrient problem is always lack of nitrogen. Although this can be overcome by the use of fertilisers, this is costly and ineffective. It is better to make use of the natural process of nitrogen fixation. However there may be severe unbalance in other nutrients, such as on serpentine soils, that has to be relieved for any growth to occur.

The final problem is the choice and re-establishment of species. If the vegetation cover is to be resilient, the species must be adapted to the local conditions of soil and climate. For biodiversity rare species should also be considered. The techniques for establishment must be chosen in relation to the biology of each species, using specially collected seed or the spreading of propagule-rich topsoil.

All this means that successful restoration depends on a programme of carefully carried out experimental ecological work.

## THE SERPENTINE FLORA OF THE BETIC-RIFFIAN ULTRAMAFIC ARC OF SPAIN AND MOROCCO

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A report is made of a botanical expedition to Southeast Spain and Northern Morocco which studied and collected the serpentine floras of the Spanish section of the Betic Cordillera in Andalusia and its extension into The Rif (Beni Bousera) in Morocco.

Phytosociological studies allowed for the identification of several communities of metal-tolerant plants. Analysis of vegetation confirmed hyperaccumulation of nickel (ca. 0.5% in dry tissue) in *Alyssum malacitanum*. This plant has potential for phytoremediation of polluted soils.

Geobotanical studies revealed the existence of several species that are unique indicators of the presence of mineral-rich ultramafic rocks. Among these are two subspecies of *Halimium atriplicifolium*.

## CARACTÈRES DE LA FAUNE DE QUELQUES MILIEUX NATURELS SUR SOLS ULTRAMAFIQUES EN NOUVELLE-CALÉDONIE

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En Nouvelle-Calédonie, les particularités de la faune des milieux sur sols ultramafiques se traduisent par un endémisme local aux niveaux spécifique et générique. De grandes différences sont cependant observées selon le groupe taxonomique considéré. L'aire de plusieurs phytophages (*Lepidoptera*, *Coccoidea*, *Thysanoptera* gallicoles...) est logiquement restreinte aux zones sur péridotites dont leurs plantes-hôtes sont endémiques. La répartition "ultramafique" de certains prédateurs, invertébrés (*Aranea*) ou vertébrés (*Squamata*), s'explique moins simplement.

Les premières études sur la structure des peuplements des arthropodes forestiers de la canopée indiquent, aux niveaux taxonomiques supérieurs (ordre, superfamille), des différences sensibles avec des milieux comparables dans d'autres aires géographiques : prépondérance des brouteurs d'épiphytes (principalement *Collembola*), importance des prédateurs autres qu'insectes (principalement *Aranea*), faible importance des fourmis. Il semble également que ces milieux hébergent une faune qualitativement riche (haute diversité) mais quantitativement pauvre (faibles effectifs par unité de surface).

Mais l'interprétation de ces observations est difficile et l'information biogéographique est souvent insuffisante pour que l'on puisse avancer des conclusions solides. La polarité des échanges faunistiques entre les zones ultramafiques et les autres zones d'endémisme en Nouvelle-Calédonie reste à préciser pour une majorité de groupes.



## THE SERPENTINE VEGETATION OF THE WOKO-GLENROCK REGION, NEW SOUTH WALES, AUSTRALIA

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A study of the xeric, serpentine vegetation at two locations in the Woko Glenrock section of the Great Serpentine Belt of New South Wales revealed it is dominated by a mallee eucalypt with affinities to montane taxa (*Eucalyptus serpentinicola*), a semi-arid hummock grass (*Triodia scariosa* subsp. *scariosa*) and a common grass tree (*Xanthorrhoea glauca* subsp. *glauca*). The vegetation contrasts markedly with adjoining eucalypt forests and rainforests growing on other substrates. An agglomerative hierarchical classification of 121 plots yielded eight floristic groups. The most xeric vegetation grows on exposed northern aspects. Soil analyses revealed a very low Ca: Mg ratio. This, along with some physical factors, is considered to explain the presence of this xeric vegetation in a humid region. *Eucalyptus serpentinicola* and *Allocasuarina ophiolitica* are endemic to the area. This serpentine vegetation is not represented in conservation reserves and much of it has been cleared for agriculture.

## **STATUT DES NUTRIMENTS ET DES MÉTAUX LOURDS DES CULTURES MARAÎCHÈRES ET FRUITIÈRES DÉVELOPPÉES SUR LES SOLS OXYDIQUES DU SUD DE LA NOUVELLE-CALÉDONIE.**

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Cette note présente le bilan de quatre années d'enquêtes agropédologiques réalisées chez quatre maraîchers des vallées de La Coulée et de La Lembi situées dans le massif péridotitique du Sud de la Grande Terre. Ces enquêtes ont comme objectif l'établissement d'un référentiel, tant pédologique qu'agronomique, sur les teneurs en nutriments et en métaux lourds du sol et des végétaux cultivés sur les principaux faciès de sols ferrallitiques des vallées en question. L'utilisation de l'espace agricole s'est fait en premier lieu en plaine alluviale et progressivement, par manque de surfaces agricoles disponibles, s'est étendue vers les pentes en zone de glacis et en zone de piedmont. Des variations apparaissent dans la composition en métaux lourds de ces trois faciès, qui se traduisent par des différences d'assimilation des éléments par les plantes cultivées. Un autre objectif de ces enquêtes est aussi d'identifier les causes des symptômes anormaux de développement des plantes cultivées.

## CHARACTERISATION OF THE SERPENTINITE SOILS OF CENTRAL QUEENSLAND, AUSTRALIA

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The largest area of serpentinite in Queensland, Australia occurs in a discontinuous belt from Marlborough to Rockhampton. The serpentinite belt is characterised by endemic vegetation communities and distinctive soil toposequences. Fifty soil profiles were described in nine transects from the top of serpentinite mountains and hills down to the footslopes and on to the adjacent alluvial plains and swamps. Six major soil groups were delineated according to morphology, parent material and landscape position. The six soil groups are :

- red clay loams on saprolite from deeply weathered serpentinite
- stony, red and brown clay loams on moderately weathered serpentinite
- shallow, stony black clays on partially weathered serpentinite
- gravelly black clays on colluvium and alluvium
- black and dark brown, cracking alluvial clays
- black cracking alluvial clays overlying magnesite

Thirty-seven soil profiles were analysed for chemical and physical characteristics. Soil fertility, cation status, particle size distribution, micronutrients and heavy metals were determined and discussed. There is a wide range in the chemical nature of the soil groups depending on the parent material and location in the landscape. Citrate dithionite free iron in red clay loams on saprolite range up to 12.5%, while calcium /magnesium ratios are as low as 0.01 in black alluvial clays overlying magnesite. Implications for agricultural management and mining rehabilitation are discussed.

## **GROWTH RESPONSES TO WATER STRESS AND SOIL TEXTURE OF TWO GENOTYPES OF *BROMUS HORDEACEUS* FROM SANDSTONE AND SERPENTINE SOILS**

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Plants growing in serpentine soils have to cope with low concentrations of important nutrients and often with toxicity caused by heavy metals. Besides, it is assumed that serpentine soil has low water content and thus plants growing in it have to be well adapted to water stress periods. In the Californian Flora, two genotypes of *B. hordeaceus* grow either in sandstone or serpentine soils. In order to compare stress tolerance, both genotypes were grown for 3 months in serpentine and sandstone soils and submitted to water stress regimes. In our experiment soil texture proved to be a major constraint for plant growth in sandstone soils especially under water stress. Growth responses and root branching patterns of *B. hordeaceus* - serpentine genotype clearly showed greater physiological adaptation to stress conditions caused by water deficiency and soil texture.

## THE PALAEOECOLOGY OF SHALLOW LAKES FORMED IN ULTRAMAFIC KARST

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Shallow lakes or swamps commonly occupy nutrient-poor internally drained basins on ultramafic serpentinite and dunite rocks, and are presumably karstic in origin. Highly organic limnic mud sections have been dated from Lake Wanda, Sulawesi, Lake Hordorli, Irian Jaya, Lake Trist, Papua New Guinea and Lakes Boulet, Emeric, Suprin, and Xere Wapo, Plaine des Lacs, New Caledonia. The equatorial sites provide sequences extending from modern back to 50-70 ka at depths of 8-10m. In New Caledonia there is no Holocene record, and dates of 17 ka to 30ka are obtained near the top of deep (5-12m) organic layers which in some cases are buried by inorganic muds derived from an erosion event. The absence of Holocene sedimentation in these sites is puzzling, and is thought to reflect the effect of tropical storms removing the upper layers periodically, although fire may play a part also.

The modern vegetation consists of open sedgelands of *Lepironia* and *Machaerina* with occasional *Eriocaulon* and *Utricularia* species and scattered shrubs of *Meterosideros* and *Melastoma*. In New Caledonia the vegetation has similar structure but includes *Melaleuca* and in one case *Podocarpus*. However pollen analyses show that the vegetation has differed in the past. In Irian Jaya a *Dacrydium* species was important, suggesting that a fringing swamp forest was present at times of high lake level. In New Caledonia abundant wood and pollen from a podocarp shows that an aquatic gymnosperm forest invaded the lakes several times in the past, often after the inwash of inorganic muds or sands. These plants are able to occupy waterlogged sites because they have porous breathing roots.

The lake sites provide a record of vegetation stability through time. The Pleistocene glacial maximum is well marked in Sulawesi and Irian Jaya by drier or higher altitude vegetation. In New Caledonia there is widespread beech forest but the climatic influence on this is unclear due to the alternations of *Gymnostoma* maquis and rainforests in association with fire. Fires around 25ka caused massive soil loss and led to a permanent change in the surrounding forests. Before that, the regeneration of rainforests took about 1500-2000 years to be completed.

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## INVESTIGATIONS INTO THE MOLECULAR MECHANISM OF NICKEL TOLERANCE IN *BERKHEYA CODDII*

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The unique ability of *Berkheya coddii* to grow on serpentine soils and to hyperaccumulate up to 36.65 g of nickel per kg dry matter, suggests the existence of a tolerance mechanism for nickel in this plant. A number of workers (e.g. Kersten *et al.* 1980; Lee *et al.* 1977) have reported such tolerance mechanisms in other hyperaccumulating plants with mainly nickel-malate and nickel-citrate being implicated in the process. In this paper we will present evidence for the nickel tolerance limits of the plant, as well as the purification and identification of various nickel-ligand complexes from leaf and root tissue. We shall also present preliminary evidence for the location of *in vivo* nickel storage sites and the potential role of these ligands in the *in vivo* detoxification process in *B. coddii*.

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## FLORISTIC DIVERSITY OF FORESTS ON ULTRAMAFIC ROCKS OF NEW CALEDONIA

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The flora of dense humid forests on ultramafic rocks is compared with that over acidic and over calcareous rocks.

The flora of forests on ultramafic rocks (1361 species belonging to 400 genera in 118 families) is as rich in species but a little less diversified in genera and families, than the flora over acidic rocks (1370 species distributed among 430 genera and 128 families). It is in contrast significantly more diversified than forest floras over calcareous rocks that cover a smaller area.

Species associated with a specific forest type are more numerous on ultramafites than on acidic rocks and the genera are equal in number in both cases.

Gymnosperms with 31 species of which 19 are strictly associated with ultramafic rocks, have their greatest importance with this type of substrate. The reverse is true for the Pteridophytes.

The total number of Angiosperms is approximately the same for both ultramafic and acidic rocks, but is very variable according to families. Thus 33 Angiosperms have a greater importance in the former rock type, 36 in the latter, and 33 are equally important in both.

With exception of the Gymnosperms that are more numerous over ultramafic rocks, taxa representative of the antiquity of the New Caledonian flora have a similar importance in the two main types of forest. Nevertheless, the families Phellinaceae, Balanopaceae, Sphenostemonaceae, Oncothecaceae, and Strasburgeriaceae are better represented in forest over ultramafic rocks. The Monimiaceae, Amborellaceae, and Trimeniaceae are more important in forest over acidic rocks. The flora of forests over ultramafites is equally well distinguished from that over acidic rocks by a greater number of species in the Euphorbiaceae, Myrtaceae, Santalaceae, Epacridaceae, Fagaceae, and Casuarinaceae. The former is also characterised by a lesser number of species in the Rubiaceae, Myrsinaceae, Leguminaceae, Moraceae, and Verbenaceae.

The number of endemic taxa is greater in the flora of forests over ultramafic rocks (1122 species in 68 genera and 4 families) than in the flora of forests over acidic rocks. The percentages of endemism at the specific level are 82.4 and 76.6 respectively for these two categories of forest.

In its entirety, the flora of forests over ultramafic rocks, is a little less rich, more original, and more largely diversified in certain groups, than is the flora of forests over acidic rocks, and contributes greatly to the richness and originality of the flora of New Caledonia.

## **ELEMENT UPTAKE PATTERNS IN AN ULTRAMAFIC FLORA, RED MOUNTAIN, NEW ZEALAND.**

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Analysis of N, P, Ca, Mg, Ni, Cu, Co, and Cr concentrations in foliage from twelve vascular plant species on ultramafic soil at Red Mountain, north-west Otago, was undertaken and the results compared with similar data published on ultramafic outcrops in northern regions of the South Island. Multivariate analyses were used to determine element uptake patterns, to distinguish the response of species with contrasting relative abundances on ultramafic soil, and to compare the floras on different types of ultramafic soil. Specifically, answers were sought to the following questions :

-1. Given that the majority of ultramafic tolerant species in New Zealand are common on other edaphically extreme soils, do plant element levels of these species reflect, when growing on ultramafic soil, any of the distinctive chemical characteristics of the soils ?

-2. If they do, which elements are involved and are there any generalised response patterns?

-3. Amongst South Island ultramafic outcrops, do element accumulation patterns on young post-glacial ultramafic soils differ from those found on older, more deeply weathered soils ?

-4. Do ultramafic endemic taxa have distinctive element accumulation patterns compared to ultramafic tolerant taxa ?

-5. Do species with low relative abundance in ultramafic vegetation differ in their element accumulation patterns from those species that are more common on ultramafic soil ?



## MÉCANISMES D'ACTION TOXIQUE DU NICKEL CHEZ LE MAÏS

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Les effets toxiques du nickel sur la croissance et la physiologie de plantules de maïs (*Zea mays* L., cv. XL 94) ont été suivis pendant 8 jours. En culture sur solution de Hoagland diluée 4 fois, la croissance des parties aériennes, et surtout des racines, est fortement diminuée pour des concentrations de  $\text{NiCl}_2$  supérieures à  $20 \mu\text{M}$ , et cela dès le quatrième jour de culture. Les effets toxiques du nickel sur la structure du maïs ont été observés en microscopie photonique. Avec  $60 \mu\text{M}$  de Ni, l'activité mitotique au niveau du méristème racinaire est diminuée de 80 % après 8 jours. Cela permet de rendre compte du ralentissement important de la croissance des racines exposées au nickel. Cette diminution de l'activité mitotique serait due en partie à une baisse de la fourniture de saccharose au méristème racinaire, suite à un blocage de la dégradation d'amidon dans les chloroplastes des feuilles. Une localisation tissulaire du nickel a été effectuée par différentes techniques. Il en ressort que le nickel s'accumule en quantité relativement importante au niveau du méristème racinaire, ce qui pourrait également intervenir directement dans la diminution de son activité mitotique.

## THE SUITABILITY OF SERPENTINE FLORA FOR THE REVEGETATION OF CHRYSOTILE ASBESTOS TAILING DUMPS

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Previous attempts in revegetating chrysotile asbestos tailing dumps have generally proved unsuccessful and costly. The primary reason has been the toxic and inhospitable nature of the tailings. Although toxic, these tailings typify neighbouring serpentine sites, which do support plants. These tolerant plants may either be endemic to these sites or merely tolerant ecotypes of a non-endemic taxon.

The aim of this study was to compare a tolerant endemic (*Berkheya coddii*) to a non-tolerant species (*Berkheya seminivea*), and to compare the serpentine and non-serpentine ecotypes of *Cynodon dactylon*. Thus trying to establish whether serpentine taxa are more tolerant of the tailings than their non-serpentine counterparts, and therefore give an indication of their potential for revegetation.

A greenhouse experiment was carried out, which comprised the germination and/or growth of the plants on four media (i- nil, ii - untreated tailings, iii - ameliorated tailings (tailings plus sawdust) and iv - chemically treated ameliorated tailings). Qualitative and quantitative measurements of survival, vigour and tolerance were measured. In most of these measurements strict attention was given to below-ground and above-ground partitioning of biomass since it serves as a good indicator of tolerance. Results revealed conclusively that the serpentine plants had a greater survival potential, vigour and tolerance. This suggests that endemic taxa are more suitable candidates for the revegetation of the asbestos dumps.

## RÉHABILITATION DES SITES MINIERS SUR ROCHES ULTRAMAFIQUES

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La Nouvelle-Calédonie, de par son climat sub-tropical et son relief très marqué notamment sur les roches ultramafiques développant des sols fragiles, est le lieu de phénomènes érosifs très importants.

La sensibilité des sols à l'érosion est aggravée par les actions anthropiques destructrices, comme le feu et l'exploitation minière du Nickel.

A l'heure actuelle, la phase de réhabilitation qui doit suivre l'exploitation minière passe par la végétalisation de vastes surfaces, présentant des contraintes écologiques très sévères (pente, granulométrie, nature et hétérogénéité des substrats, régime des pluies etc...)

Cette remise en état permet de réaliser l'intégration des sites dans leur environnement naturel et paysager, de garantir la stabilité à long terme des surfaces traitées et ainsi de diminuer les coûts ultérieurs d'entretien.

S'appuyant à la fois sur les travaux menés depuis une dizaine d'années par les organismes de recherche locaux (L'ORSTOM et le CIRAD-Forêt), et sur son expérience et son savoir faire acquis dans d'autres pays d'Europe ou de la zone tropicale, la société SIRAS, à travers sa filiale SIRAS PACIFIQUE, développe, depuis 1993, en Nouvelle-Calédonie, des procédés de lutte contre l'érosion et de végétalisation par plantation et semis hydraulique. Cette dernière technique étant seule à permettre le traitement de vastes surfaces d'accès difficile.

L'objectif des réalisations est d'implanter une végétation résistante, pérenne, à base d'espèces natives donc parfaitement adaptées aux conditions du milieu à réhabiliter, capable de relancer la dynamique de la végétation sur ces sites dégradés et donc, à terme, de recréer le lien avec la végétation environnante. Ces espèces natives sont des plantes herbacées (Cypéracées) et ligneuses, endémiques pour la plupart et inféodées au substrat "minier".

L'explication de la démarche employée, de la collecte des graines jusqu'à la mise en œuvre des procédés de végétalisation, met en évidence la nature des difficultés rencontrées à chaque étape.

En effet, l'adaptation des techniques éprouvées ailleurs aux conditions édaphiques sur roches ultra-mafiques et bioclimatiques locales, n'est pas sans poser un certain nombre de difficultés.

Des premières réalisations sont tirées des enseignements et des voies de recherches visant l'amélioration des techniques de végétalisation et de lutte contre l'érosion : sélection et production du matériel végétal, enrobage de graines, amélioration des fertilisants, fixateurs, conditionneurs de sols et mulchs.

Ces recherches appliquées font l'objet d'une thèse depuis 1993, réalisée en collaboration entre SIRAS PACIFIQUE, l'Université Française du Pacifique et l'ORSTOM sur les sites miniers de la S.L.N

## STUDIES ON THE VEGETATION OF PHILIPPINES MOUNTAINS ON ULTRAMAFIC ROCKS

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Vegetation on ultramafic rocks constitute a unique type in the Philippines which is distinct from the other types of forest such as the lowland evergreen forest and the montane forest. This type of forest is found scattered in the Philippines from Luzon, the Visayas and Mindanao. However, their area of coverage is limited and usually does not extend widely in contrast with the other forest types.

Floristic and biological knowledge about the vegetation on ultramafic rocks in the Philippines is very scanty. In fact this forest type is not even described or recognized as a distinct vegetation until the early 1980's

Initial study on the floristic composition of this forest type in Mt. Bloomfield, Palawan shows that the common families are Loganiaceae, Dilleniaceae, Verbenaceae, Myrtaceae, Gonystylaceae, and Ebenaceae. Determination to the species level is currently being undertaken at the PNH with the help of botanists from Rijksherbarium, the Netherlands.

Further floristic and ecological studies on ultramafic rocks from different parts of the country is planned in the near future.

## **SUCCESSIONAL PATTERNS IN *GYMNOSTOMA* MAQUIS ON ULTRAMAFICS IN SOUTHERN NEW CALEDONIA: THE ROLE OF FIRE.**

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In many regions of New Caledonia, the ultramafic maquis appears to possess fire adapted traits in addition to being adapted to substrate conditions (Morat *et al*, 1986 b). Selection of species in these communities may favour fire adapted taxa over ultramafic species. A phytosociological survey was conducted in *Gymnostoma deplancheanum* communities in southern New Caledonia to identify floristic changes which may suggest a fire related succession pattern. Fire adapted responses of the more common species were also recorded for these communities to both quantify the succession pattern and possibly identify the biogeographic origins of fire tolerance in New Caledonia.

MDS ordination of the floristic survey combined with a succession index best explains the variance in the data suggesting the pattern is successional. There appear to be 4 different floristic groups which occur at different times since fire. The first early colonist phase is dominated by vegetative regenerating genera shared largely with the Australian region. Later succession steps are dominated by obligate seeders which facilitate subsequent colonisation of sensitive maquis and forest taxa.

It appears that fire adaptation in New Caledonian maquis originated from ancestral Gondwanan taxa prior its separation. These sclerophyllous taxa may have increased their radiation on ultramafics during fire promoting dry periods. A second evolution possibly took place in New Caledonian forest taxa in response to dry conditions and led to the creation of fire adapted endemic genera.

**THE IMPORTANCE OF CALCIUM-MAGNESIUM RATIO IN THE LIMESTONE USED TO DETOXYIFY AND REVEGETATE ACIDIC, NICKEL- AND COPPER CONTAMINATED SOILS IN THE SUDBURY, CANADA MINING AND SMELTING AREA.**

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One hundred years of logging, fire, acidification by sulphur dioxide, particulate nickel and copper deposition, enhanced frost action and soil erosion have created extensive tracts of barren land surrounding the Sudbury nickel and copper smelters. Following recent improvement in atmospheric quality, the principal factors limiting plant colonization reside in the soil, mainly in the form of nickel, copper and aluminum toxicity. The soil can be detoxified by manual application of ground limestone to the surface, after which a grass-legume mixture can be established from seed, and natural recolonization by woody species begins. It has been observed that, on many barren sites, plant growth is better on soil treated with dolomitic limestone than with calcitic limestone. Greenhouse experiments using mung beans (*Vigna radiata*) have shown a striking improvement in shoot growth on certain contaminated soils when the limestone is dolomitic rather than calcitic. A similar response in shoot growth to increased Mg:Ca ratio in the limestone occurred in redtop (*Agrostis gigantea*), a grass species used in the Sudbury revegetation program. Although the response in redtop was less striking than that in mung bean, it was statistically significant, and was found over a wider range of contaminated soils.

## LES GISEMENTS CUPRO-COBALTIFÈRES DU SHABA (ZAIRE) - ÉTUDES FLORISTIQUE ET ÉCOLOGIQUE.

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Dans leur ouvrage magistral "Cuivre et végétation", Duvigneaud et Denayer-De Smet (1963) dresse une première liste de quelques 160 plantes observées sur les anomalies cupro-cobaltifères du Shaba. Ils y distinguent plusieurs groupes socio-écologiques auxquels ils rapportent un certain nombre de taxons.

Vingt ans plus tard, un inventaire actualisé fait état de 240 espèces végétales (Brooks et Malaisse 1985).

La prospection de terrain poursuivie de 1975 à nos jours par Malaisse et ses collaborateurs a permis la récolte de quelques 1350 échantillons d'herbier en provenance de 43 des 120 gisements métallifères identifiés.

L'étude de ce matériel ainsi que des récoltes antérieures a été poursuivie. Elle a fourni un exemple de conclusions originales (Malaisse 1995) ; en outre une liste de plus de 330 espèces a été dressée.

Ce dernier inventaire est analysé

- du point de vue de la diversité des familles phanérogamiques qui montre une séquence fort différente de celle de la flore serpentinique ;
- en ce qui concerne l'aérogénie des taxons reconnus ; à partir de cette analyse l'existence d'un endémisme local important est mise en évidence ; il est quantifié et commenté ;
- en regard du comportement socio-écologique des principaux taxons vis-à-vis de la teneur en eau et en métaux lourds du sol.

Notre étude aboutit à caractériser la flore cupro-cobalticole des points de vue de ses origines multiples, de ses adaptations phygéochimiques et de ses potentialités à verduriser les sites pollués par les métaux lourds ou altérés par une forte activité anthropique.

## **REVEGETATION AFTER LATERITIC NICKEL MINING AT P.T. INTERNATIONAL NICKEL INDONESIA**

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P.T. International Nickel Indonesia (P.T. INCO) is a fully integrated mining and smelting company, with its project located in the central portion of the Eastern part of Sulawesi, Indonesia. This area is covered by nickeliferous laterite in various thicknesses and grades. The laterite itself is a residual soil product of the chemical and physical weathering process, which develops typically under tropical climate.

Parallel to production increase and the target to reduce exposed area from previous mining activities, the approaches of selecting revegetation method and development post mining land use has been proposed and given a successful result to P.T. INCO's revegetation.

By those approaches, P.T. INCO has been able to revegetate 134 hectares in 1994 which is a dramatic improvement compared to the previous year. Not only the coverage area was increased but also growth rate, degrees of survival and roots extension are improved. Following the expansion plan and to minimize the opened areas, P.T. INCO should be able to revegetate more than 200 hectares per year until the end of this century.

The strategies of developing revegetation, methods, problems faced and research carried out to improve post mining land use are described in this paper. When the project ends, it is expected that the revegetation activities will not only be protected, but will also protect endangered species and post mining land use will become more productive.



## **NUCLEAR MICROPROBE INVESTIGATION OF NICKEL DISTRIBUTION IN ORGANS AND CELLS OF HYPERACCUMULATING PLANTS**

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In South Africa, four species, all from the family Compositae, are known as nickel hyperaccumulators.

The distribution of nickel and other elements in freeze-dried organs and cells of these species was investigated. Studies were performed using the NAC scanning nuclear microprobe. Its newly implemented, true elemental imaging system (Dynamic Analysis) is particularly suitable to study the distribution of elements in plant tissue, with detection limits far better than those achievable with scanning electron microprobes.

Quantitative elemental maps in biological specimens are still rarely reported and previous studies of Ni hyperaccumulation were restricted to qualitative evaluations in which some elemental interferences, for example between Ca ( $K\alpha$ ) and K ( $K\beta$ ) were present. Two-dimensional, quantitative maps of distribution of nickel and macro- and micronutrients were obtained. The highest nickel enrichment was found in the epidermis of leaves. Studies at the cellular level showed that it was mostly concentrated in the cell walls of the epidermis layer. The relations between nickel and other elements were also investigated.

These results could be useful in explaining the transport of ions and metal detoxification mechanism in hyperaccumulating plants.

## INFLUENCE OF ROOT EXUDATES ON METAL MOBILIZATION

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Plant roots induce changes at the soil root-interface as they release inorganic and organic compounds (*i.e.* root exudates) in their rhizosphere. Availability of elements in the rhizosphere can be directly or indirectly increased (mobilization) or decreased (immobilization) by root exudates.

The study of the specific properties of root exudates requires hydroponic and sterile cultures. Exudates can also be collected from plants grown in the field. Root induced changes in soil properties can be observed using non-destructive agartechniques with indicator (*e.g.* pH).

The amount of exudates released by living roots varies from 1 to 30% of the net photosynthesis according to the plant species and growth conditions. Exudates vary in nature and origin, and include several compounds of low (LMW) and high molecular weight (HMW).

Mobilization and immobilization of elements in the rhizosphere can be due to changes in pH (*e.g.* increase or decrease of pH due to imbalance in cation/anion uptake ratio), release of complexing substances (organic acids, phenolics), changes in redox potential and increases in microbial activity (bacteria and mycorrhizae). Complexation of metals around the roots is an important process, and metal binding ability of exudates depends on the nature of the element. Enhanced release of particular root exudates can be observed as a response to conditions of inadequate nutrient supply. Examples are release of phytosiderophores in graminaceous species for iron or zinc acquisition in substrates low in available Fe or Zn, organic acids and protons (*e.g.* citric acid in white lupin) in response to P deficiency. Increase in mobility of metals can also be induced indirectly by the form of the nitrogen fertilization. When N is supplied as ammonium, uptake of the toxic metal Cd is higher than in presence of nitrate as a result of an enhanced release of protons in the rhizosphere in the presence of the cationic form of nitrogen.

Root exudates play an essential role in the mobilization of metals in the rhizosphere. In the perspective of using plants to remove toxic metals from polluted soils, the processes of metal mobilization that take place at the soil root interface of hyperaccumulators should be well described.

## **NUTRIENT ADDITION EXPERIMENTS ON ULTRAMAFIC SOILS : ARE THEY WORTHWHILE ?**

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Nutrient addition experiments to ultramafic soils have been employed for many years and given much information. The value of these experiments - in the field and in the glasshouse is assessed. New data are given for Scottish sites and the value of combining the nutrient addition studies with those of population dynamics are discussed.

## ECOLOGY AND BIODIVERSITY OF THE SYMBIOSIS *FRANKIA*-CASUARINACEAE IN NEW CALEDONIA

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The native region of Casuarinaceae family (actinorhizal plants) is Oceania (Australia and Indo-Pacific islands). In New Caledonia, in spite of the reduce area, a great number of endemic Casuarinaceae is present. In fact, 8 species of *Gymnostoma* out of the 18 which make up this genus and 1 species of *Casuarina* are originated from New Caledonia. The two genera, except 1 species, occur in soils derivated from ultramafic rock and are adapted to poor and toxic soils. Futhermore, actinorhizal plants can establish nitrogen-fixing symbioses with the slow growing actinomycete *Frankia*. Because of their ecological characteristics, actinorhizal plants frequently occur as pioneer vegetation and are used in rehabilitation of degraded sites.

This work was a first study of the ecology of the symbiosis Casuarinaceae-*Frankia* in New Caledonia. It was focused on two major topics. The first part will be concerned with the symbiosis, particularly with cross-inoculation trials using crushed nodule suspension as inoculum. The biodiversity of the microsymbiot *Frankia*, in relation with plants species and soil, will be analysed in the second part.

The results obtained, show that this symbiosis is characterized by a great biodiversity. Inside the *Gymnostoma* group, no host specificity was observed. These results were obtained by cross-inoculation tests and molecular characterization of *Frankia*. Futhermore, no correlation was shown between site or soil and diversity of *Frankia* strains.

**MONITORING NATURAL AND REINTRODUCED POPULATIONS OF THE  
ENDANGERED SERPENTINE ANNUAL *ACANTHOMINTHA DUTTONII*.**

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*Acanthomintha duttonii*, the San Mateo thornmint (Lamiaceae), once comprised four populations in San Mateo County, California. Two decades of urban development have left only one population in serpentine grassland habitat at Edgewood County Park. Our efforts to conserve the species have included long-term demographic monitoring to determine the factors that limit the growth of the natural population. In addition, we have attempted to reintroduce the species to suitable habitat within historic range by creating a new population at Pulgas Ridge. Our studies of the natural population have given us criteria with which to evaluate the success of our reintroduced population. Dramatic fluctuations in the size of the natural population appeared to correspond most closely with changes in plant size and reproductive output from year to year. Such variation was also observed in the reintroduced population at much lower densities. The results suggest that the conservation of *A. duttonii* and other similar serpentine species must be long-term, iterative projects that take such variability into account. This work was funded by US Fish and Wildlife Service and the California Department of Fish and Game.

## SOILS AND VEGETATION OF SOME MALESIAN ULTRAMAFIC SITES

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Recent work on many plots on the ultramafic mountains of Silam (Sabah), Bloomfield (Palawan, Philippines), Giting-Giting (Sibuyan, Philippines), and Piapi (Talaud Islands, Indonesia) is briefly described. All these areas are in the wet tropics and yet the vegetation they bear ranges from almost none (patches on Bloomfield) to large stature lowland dipterocarp forest (on Silam) and ranges in species richness from the monodominant stands of *Casuarina* (on Bloomfield) to extremely species rich lower montane forest (on Silam). The causes of these differences are discussed and a simple explanatory model is discussed to provide testable hypotheses about the relationships of ultramafic soils to forest stature. Species richness remains an intractable enigma !

## **MINÉRALOGIE ET CONTRAINTES ÉDAPHIQUES DES SOLS DÉRIVÉS DE ROCHES ULTRABASIQUES EN NOUVELLE CALÉDONIE**

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Les sols "ferritiques" dérivés de roches ultrabasiques ont une grande importance en Nouvelle-Calédonie en raison de leur grande étendue et de leur propriétés édaphiques particulières dues à une abondance exceptionnelle en certains éléments, notamment Fe, Mg, Ni, Cr, Mn et Co, et à une carence en Ca, K, P, Cu, Zn et Mo, voire en Si.

Deux toposéquences de sols ferritiques ont été observées dans le Sud de la Nouvelle-Calédonie (Ouénaou, vallée de la Coulée). L'objectif de cette communication est de montrer la relation entre la disponibilité de certains éléments (Mg, Mn, Ni, Cr et Co), qui peuvent causer un déséquilibre nutritionnel ou une toxicité pour la plante, et la présence de certains constituants minéraux du sol ainsi que la localisation de ces minéraux dans le profil et la toposéquence de sol.

Les constituants minéraux ont été analysés par diffraction de rayons X sur poudre de sol puis observés sur lame mince en microscopie optique, puis en microscopie électronique à balayage (MEB) couplée à une analyse chimique élémentaire in situ des différentes phases minérales (nodules, plasma, minéraux primaires sains et altérés...).

les sols "ferritiques" sont essentiellement constitués d'oxydes métalliques (de Fe, Al, Cr, Ni, Mn et Cr), la goéthite alumineuse et un peu nickélicifère étant largement dominante (60 à 90 %); Parmi les silicates magnésiens prédomine le talc un peu nickélicifère ou non. Il existe également un silicate de magnésium nickélicifère qui paraît non cristallin ou mal cristallisé (DRX, MEB). La distribution de ces minéraux n'est pas homogène, à part la goéthite : elle dépend de la composition des matériaux originels, de sa distribution spatiale dans le profil de sols et suivant la toposéquence.

La composition chimique globale des minéraux ne permet pas de prévoir la disponibilité des éléments Mg, Mn, Ni, Co et Ca pour la plante. Des dissolutions chimiques sélectives et séquentielles ont été faites par Hcl 2N et par l'oxalate d'ammonium, ainsi que des extraits sélectifs par KCl et par DTPA.

Deux éléments sont en abondance inhabituelle sous une forme très soluble : le nickel et le manganèse. La forte disponibilité du nickel semble liée à un silicate de magnésium non cristallin ; celle du manganèse l'est à un oxyde non cristallin de manganèse et de cobalt. L'abondance de ces éléments sous une forme très soluble dépend du matériau originel et de son altération incomplète (altérite) ainsi que de la localisation du sol dans la toposéquence.

**POPULATION DYNAMICS IN SOME RAINFORESTS ON ULTRAMAFIC SOILS IN NEW CALEDONIA, AND THEIR IMPACT ON PATTERNS OF CANOPY RICHNESS.**

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Permanent plots are being established in monodominant and mixed rainforests over a range of altitudes on ultramafic soils in New Caledonia to investigate the factors determining canopy richness. Initial studies are examining the dynamics of the major tree species to assess the role of disturbance and successional change in controlling the canopy richness of these stands. The monodominant stands being investigated are dominated by *Nothofagus* spp. and have a high species richness in the understorey, despite the low richness of the upper canopy. Many of the species recorded in the understorey are potentially capable of reaching the canopy, including species that typically occur in the canopy of nearby mixed rainforests. However, the dominant canopy species of *Nothofagus* are rare as saplings, with the population sample showing a bell-shaped size distribution. It therefore appears that these *Nothofagus*-dominated forests are successional, and in the hypothetical absence of disturbance the *Nothofagus*-dominated canopy is likely to be replaced by a species rich canopy similar in composition to the adjacent mixed rainforests.

Study of adjacent mixed rainforests suggests that these too are seral forests, with many of the common canopy species not represented in the understorey. Some of the canopy species are well represented in the smaller size classes, and there are few canopy species occurring in the understorey which are not also represented in the canopy. Therefore these forests may eventually become less species-rich as the forest ages, with only the most shade-tolerant species occurring in the canopy.



## THE DISTRIBUTION AND BIOGEOCHEMISTRY OF SOME SERPENTINE PLANTS OF GREECE AND THE AEGEAN REGION

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The elemental composition of soils and their associated flora have been investigated in several notable ultramafic areas of Greece, including those near Thessaloniki and Larimna, on the Greek mainland, and on the islands of Tinos, Lesbos and Crete. A list of species found on five serpentine areas on Crete is given : *Alyssum fallacinum* appears to be the only serpentine-endemic plant of Crete.

In Greece, nickel hyperaccumulation appears to be confined to the Brassicaceae (*Alyssum*, *Bornmuellera*, *Peltaria*, *Thlaspi*), although moderately high concentrations are found in some serpentine occurrences of *Silene* species. Where nickel-accumulating, serpentine-endemic *Alyssum* species occur, they act as reliable indicators of the extent of ultramafics ; on undisturbed areas they are often among the most abundant species, and on ground previously disturbed for agricultural or mining purposes they may form almost a monoculture. They are not, however, present on all ultramafic outcrops of the islands or regions to which they are endemic.

## **RELATIONS ENTRE LES TENEURS EN NICKEL, MANGANESES ET COBALT DE QUELQUES ESPECES DES MAQUIS MINIERES ET LES RISQUES DE TOXICITE EN CES ELEMENTS DU SOL.**

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L'étude porte sur l'analyse des variations de teneurs en nickel, manganèse et cobalt dans les tissus foliaires de 12 espèces croissant naturellement sur 5 catégories de sols issus de roches ultramafiques.

La variation des teneurs en ces 3 éléments au sein d'une même espèce sur différents substrats traduit la différence de concentrations de ces éléments sous forme assimilable dans le sol. Elle rend compte par là même des risques de toxicité plus ou moins importants pour les plantes.

Ces risques sont en ce qui concerne le nickel relativement faibles sur oxisols gravillonnaires ou cuirassés, et élevés sur oxisols colluvio alluviaux hydromorphes. En dépit de teneurs en nickel total élevées, ils apparaissent moins importants sur oxisols remaniés d'érosion que sur sols colluvio alluviaux hydromorphes.

Les risques de toxicité en manganèse sont les plus importants sur oxisols colluvionnés de piedmont et les plus faibles sur sols bruns hypermagnésiens et sur oxisols remaniés d'érosion. Ils sont intermédiaires sur oxisols colluviaux hydromorphes et sur oxisols gravillonnaires ou cuirassés, mais varient beaucoup dans ces 2 cas d'une station à l'autre.

Les teneurs en cobalt dans les espèces analysées sont relativement faibles sauf pour les Cunoniacées et ne permettent pas de préjuger de l'existence de risques de toxicité dans l'une ou l'autre catégorie de sol.

Il apparaît que les variations de teneurs en nickel ou manganèse foliaire de certaines espèces des maquis miniers, et notamment de celles qui ont la capacité d'absorber et de tolérer des quantités relativement importantes de ces éléments dans leurs tissus, apportent des indications sur les risques de toxicité en ces éléments du sol.

## CHEMICAL PROPERTIES OF LEACHATE SAMPLED WITH POROUS CUP LYSIMETERS FROM TWO SITES WITH SERPENTINIZED ROCKS, NEWFOUNDLAND, CANADA

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Areas with serpentinized rocks cover about 3% of the 106,000 km<sup>2</sup> of the island of Newfoundland. These areas stand out as reddish-brown rock deserts contrasting greatly with the adjacent green Boreal Forest vegetation. In soil and vegetation studies a number of stress factors have been identified including cryoturbation and high Mg concentrations (12-16%, total, 6.8-16.64 m-equiv/100g, available) with possible toxic quantities of Ni (0.3-0.4%, total, 0.008-0.031 m-equiv/100g available). The Mg/Ca quotients are 50-100 total, 3-30 available and 5-10 in water extracts. Soils are close to neutral in reaction but are acid in organic areas and available Ni increases. Noteworthy aspects of the flora and vegetation includes cover of about 10%, which includes about half the adjacent vascular flora with four hyperaccumulators of Ni and 10 other species are strong accumulators of Ni and other heavy metals.

To investigate the fluxes in soil water and to establish if toxic pulses of Mg and heavy metals exist, current work reported in this paper focuses on soil leachate measured with porous cup lysimeters (0.51 capacity). Leachate was collected every two weeks for two different sites for the growing season mid May-November. The TM site is an alpine Boreal site from West Newfoundland and the NWG site is a Boreal lowland Central Newfoundland site. Both sites have Orthic Regosols and shallow organic topped Rego-Gleysols. The NWG site was monitored in 1992 & 1993 and the TM site 1993 & 1994. Leachate was analyzed for N (Ammonia, Nitrate, Nitrite), P, K, Ca, heavy metals and pH.

The TM site has three different substrate characteristics : A) Typical barren Regosols B) Shallow organic fens C) Active calcium seep areas. Leachate from A had a pH range of 7-8, a 5-35 Mg/Ca quotient, low P & K with most N as Nitrate (0.2-0.5 ppm). Leachate from B had a pH range of 6.5-7.5, a 5-40 Mg/Ca quotient, low P & K with most N as Ammonia (0.05-0.2 ppm). Leachate from C had a pH range of 8-10.5, a Ca/Mg quotient of 5-40, low P & K with most N as Nitrate (0.2-0.3 ppm). Fe, Ni & Co were highest in B (ie. the organic areas). Ni concentrations ranged from 72-195 ppb in B, were consistent (14-18 ppb) in A. Trace amounts of Cr were only present in A.

The lowland Boreal site NWG had no detectable Ca seep areas. The pH ranged from 7-8, the Mg/Ca quotient 20-40 increasing greatly in the freeze/thaw period with most N available in Nitrate form. Seasonal patterns and pulses are also discussed in this paper.

## SYLVICULTURE DES TERRAINS MINERS DÉGRADÉS

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La réussite des plantations dans les terrains dégradés, sur sols ultrabasiques, nécessite un effort particulier. Sur ces terrains la recolonisation naturelle est pratiquement impossible. Les travaux de recherches menés depuis une vingtaine d'années ont permis cependant de mettre au point des méthodes qui aujourd'hui donnent de bons résultats. Des réalisations à grande échelle sont désormais entreprises, en particulier par la Province Sud (Col de Plum). Ces travaux nécessitent des moyens financiers importants, car ils demandent un apport important en matière organique et en paillage, mais les résultats obtenus à partir des deux espèces les plus utilisées - *Acacia spirorbis* et *Casuarina collina* - sont très encourageants. L'intérêt d'utiliser une gamme plus large d'espèce est cependant aujourd'hui largement reconnu. Les recherches actuelles portent donc sur de nouvelles espèces locales à croissance prometteuse, et dont la multiplication est totalement maîtrisée. L'association avec des Cypéracées devrait en outre permettre une meilleure couverture des sols.

## GENETIC DIFFERENTIATION OF *CERASTIUM* ON SERPENTINE

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The genus *Cerastium* (Caryophyllaceae) has in northern Europe an intricate complex of polyploid perennial herbs. We are here concerned with four taxa : *C. alpinum*, *C. glabratum* and *C. fontanum*, which have serpentine forms, and *C. arcticum*. *C. glabratum* is the most characteristic inhabitant of serpentine soils, while *C. arcticum* grows off serpentine on high arctic or high alpine habitats. Morphological differentiation is found within these taxa. *C. alpinum*, *C. glabratum* and *C. arcticum* constitute a chain of forms.

To study the effect of serpentine on the genetic differentiation of the genus *Cerastium* we have collected plants from twelve populations ranging from central Norway through Sweden to eastern Finland across habitats ranging from high alpine non-serpentine to alpine and lowland serpentine soils. The genetic structure of these populations was studied with starch gel enzyme electrophoresis. An analysis of the enzyme phenotype patterns shows that the amount of self-fertilization and vegetative reproduction varies among populations. The lowland serpentine populations from Finland are isolated and differ genetically from the serpentine and non-serpentine populations in Sweden and Norway. High alpine populations include hybrids between *C. alpinum* and *C. arcticum*. In addition, the serpentine form *C. fontanum* subsp. *vulgare* var. *kajanense* is genetically similar to the nearby non-serpentine form. Glabrous *C. glabratum* plants show great similarity in enzyme phenotypic patterns to nearby hairy *C. alpinum* individuals. Accordingly, the various serpentine forms recognized within the complex are not genetically distinct. They rather represent populations of arctic and alpine plants that have been able to colonize an extreme serpentine environment. Even though there is morphological differentiation on serpentine within the genus *Cerastium* in northern Europe, the underlying genetic differentiation is limited. This may be expected, given the young age of the northern European flora.

## ROLE OF METAL TRANSPORT AND CHELATION IN NICKEL HYPERACCUMULATION IN THE GENUS *ALYSSUM*

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A number of plants endemic to ultramafic substrates accumulate high concentrations of nickel in their above-ground biomass. These « nickel hyperaccumulators » are of great interest both as models for understanding the biochemical basis of metal tolerance in plants, and because of their potential use in the remediation of polluted soils

We have been studying the relationship between nickel hyperaccumulation and nickel tolerance in the genus *Alyssum* to investigate the way in which nickel is translocated from root to shoot. On exposing plants grown in solution culture to nickel, the hyperaccumulator species show distinctive changes in the amino-acid composition of their xylem sap, sampled as root-pressure exudate. Since this response is not observed in the non-hyperaccumulator species, we suggest these amino acids act as nickel-chelating ligands and play a key role in the underlying mechanism of nickel tolerance.

## POTENTIAL FOR MANAGEMENT OF NICKEL AND CHROMIUM IN ULTRAMAFIC AND CONTAMINATED SOILS

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Management of contaminated soils is of increasing concern throughout the world due to the rising population and demand for enhanced high quality food production. In particular, heavy metal contaminants enter the soil environment through both anthropogenic and natural sources. While inputs through anthropogenic sources may be controlled by both disposal rates and modernization of the industrial processes, natural inputs mostly depend on the controls imposed by the soil environment. However, natural inputs are largely considered insignificant in most soil environments, the only exceptions being the soils formed on mineral ore containing parent materials (eg, lead, arsenic ores, etc) and ultramafic soils. Ultramafic soils derived from serpentine are typically disproportionately rich in magnesium (Mg) and heavy metals such as nickel (Ni), chromium (Cr) and cobalt (Co) and poor in calcium (Ca) and one or more of several nutrient ions (K, N, P, Mo). Consequently in these soils, nutrient imbalances and the high heavy metal (Cr and Ni) concentrations have been reported to cause depressed growth of certain plant species that grow well in uncontaminated soils. In contrast, certain native plant species that have the potential to accumulate metal ions predominate in ultramafic soils. It has been suggested by numerous investigators that such metal accumulator plants could be used for the removal of heavy metals from contaminated soils. This overview addresses some of the soil factors that may be controlled to enhance soil-plant transfer of metals to maximise their uptake by accumulator plants. After harvest, the heavy metals in the plant tissue would be recycled.

## THE UPTAKE OF NICKEL BY HIGH TOLERANT GENOTYPES OF *MIMULUS GUTTATUS* FISCHER EX DC, FROM SERPENTINE AND COPPER MINE HABITATS

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*Mimulus guttatus* Fischer ex DC is indigenous to wetland pastures and the serpentine streams of North America. Relatively recent adaptation of this species to the streams of disused metal mines, has prompted interest in its ability to tolerate high levels of cadmium, copper, chromium, nickel and zinc and the removal and accumulation of these metals from contaminated mine run - off and soil.

Lethal doses (EC100) for *M. guttatus* derived from an uncontaminated pasture were assessed from dose responses for nickel, chromium, zinc, mercury and cobalt. 60 individuals of *M. guttatus* from both a serpentine outcrop (Idria) in central California and a copper mine (Copperopolis) in Calaveras County, CA., were grown up and screened at the EC100 level for these five metals. The Copperopolis population exhibited higher tolerances to zinc and chromium whereas the Idria population yielded higher tolerances to nickel and mercury. After selection of high tolerant nickel genotypes from both populations, comparative nickel uptake experiments were run for three weeks at 5 concentrations. Solutions were changed every 48 hours and 10 ml. water aliquots were taken to assess the nickel removal potential from contaminated water. In vivo biomass was determined using volume displacement flasks.

In addition, the genetics of tolerance to and uptake of nickel has been investigated using three sets of crosses : selfed high tolerant nickel genotypes from both sites ; crosses between high tolerant nickel genotypes within and between both sites ; and crosses between high tolerant nickel genotypes and non-tolerants.



## PROPAGATION OF PLANT SPECIES OF THE NEW CALEDONIA ULTRAMAFIC MAQUIS

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In present day understanding of the procedures for rehabilitation of mining areas, it would be considered *de rigueur* to utilise strictly those species indigenous to the specific area. This would be particularly the case in New Caledonia where "islands" of ultramafic rock frequently have high endemism. Hence wide knowledge of propagation requirements across the floral spectrum is required for success. As part of a project to develop a New Caledonian section in the Royal Botanic Gardens, Melbourne, in the state of Victoria, Australia, three expeditions have been made in order to collect propagation material of a wide range of species.

Most of the rare gymnosperms have been propagated successfully, including *Libocedrus* spp., *Podocarpus decumbens*, *Neocallitropsis*, *Acmopyle*, *Dacrydium* spp. and *Falcatifolium*, all from cuttings. Significantly, *Dacrydium guillauminii* has proved particularly amenable to cultivation. With *Falcatifolium* established, it has been possible to undertake work with *Parasitaxus* scions. In some cases, where seed was not available, we have used grafting, e.g. *Agathis montana* onto *Agathis robusta*. Some rare species such as *Dacrydium guillauminii*, *Retrophyllum minor* and *Austrotaxus* have been grown from seed germination times ranging from one month to 18 month (for *D. guillauminii*).

Other material of significance from maquis heathlands which has been propagated (other than by seed) includes : *Astelia*, *Xeronema*, *Grevillea*, *Stenocarpus*, *Alphitonia*, *Metrosideros* and *Callistemon*. From seed we have had much success ranging from *Arillastrum*, *Gymnostoma* and *Xanthostemon* species to *Nepenthes* etc. Difficult species have included *Geissois* (by aerial layering) and *Doubouzetia*. Despite initial propagation success, it is obvious that there are significant problems in continuing to grow on many species, e.g. phosphorus/nitrogen sensitivity.

From our work, we can conclude that it is likely that in any rehabilitation project it is possible to collect and propagate a very representative range of plant species from the fabulous flora of the New Caledonian maquis.

## SILENE DIOICA AND ITS ADAPTATION AND EVOLUTION ON SERPENTINE

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*Silene dioica* (Caryophyllaceae) is a most characteristic member of the Scandinavian plant community but it is also widespread outside serpentine. I have studied the effect of long-time exposure to serpentine stress by comparing the population genetic structure, the plant growth and the morphology of plants in serpentine and nearby non-serpentine populations. The genetic structure of *Silene* populations, analyzed by enzyme electrophoresis, did not imply a direct selection on serpentine. Serpentine does, however, isolate populations which become subject to genetic drift. This isolation may be due to the surrounding vegetation which can limit pollinator movement between *S. dioica* populations.

*S. dioica* appears to be constitutively adapted to serpentine stress since both serpentine and non-serpentine populations are tolerant to high concentrations of nickel and grow well in serpentine soils. Nickel stress *per se* does, accordingly, not create a strong selection pressure on *S. dioica*. The constitutive tolerance has made repeated colonization of serpentine possible.

Even though the adaptation to serpentine is not reflected in a specific multicolour genotype, I have found evidence for selection that acts upon the morphology. The distinctive morphological differences between serpentine and non-serpentine populations are genetically controlled and are maintained through direct selection acting upon specific traits. In addition, on serpentine both hairy and glabrous *S. dioica* plants grow. Glabrousness is a general characteristic of serpentine plant taxa. In *S. dioica*, glabrousness is determined by a recessive allele at a single locus. The glabrous form is not present on non-serpentine meadows. Slugs are important agents of selection against glabrousness on meadows since they graze selectively on hairless plants. Slugs are rare on serpentine, and a relaxation of selection evidently explains the maintenance of this genetic polymorphism.

Repeated colonization of serpentine and a pattern of convergent evolution of morphology in similar habitats suggests that the invading population, that colonized Scandinavia after the last Ice Age, contained the genetic prerequisites for adaptation to serpentine and the genetic variation that made the morphological differentiation possible.



**RÉSUMÉS**

**ABSTRACTS**

**POSTERS**



## INTERACTION BETWEEN SOLUBLE AND INSOLUBLE POOLS OF NICKEL IN SOIL

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Hyperaccumulating plants are being investigated for both polishing soils as well as biorecovery of minerals. The effectiveness of both processes, and especially the latter, depends on the interaction between the soluble and insoluble pools of the metal concerned and the possible mediation of this process by plants. This study investigated the interaction between nickel pools in soil and plants and attempted to assess whether the transfer of nickel between pools was plant-mediated. The plant species used was *Berkheya coddii* Roessl., a nickel hyperaccumulator from southern Eastern Transvaal, South Africa. Three treatments were used: 1. soil was placed in pots ; 2. soil was placed in pots with a single plant of *B.coddii* planted in each ; and 3. soil was placed in pots and was watered three times a day for two weeks, in an attempt to leach out the soluble pool of nickel. Then, all pots were placed in plastic saucers and watered from below. Analyses measured total and soluble nickel in soil and total nickel in plant tissue. It was found that : 1. The plastic pots acted as a sink for soluble nickel ; 2. Nickel appeared to move from the plant rootstock into the shoot and into the soil ; 3. The soluble nickel pool was replenished from the insoluble pool ; and 4. The experimental design and methods required considerable modification.

## EFFECT OF NICKEL HYPERACCUMULATION ON HERBIVORY IN TWO SPECIES

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Five major hypotheses have been proposed for the function of hyperaccumulation of toxic metals by some species of plants growing on serpentine soils. The most favoured of these is defence against herbivory or pathogen attack, but there is little evidence to support it. This study sought to establish whether hyperaccumulation in *Berkheya coddii* Roesl. and *Senecio coronatus* (Thunb.) Harv. reduced the extent of herbivory of leaves by invertebrates (specifically slugs). Seven experiments were conducted, in which slugs had a choice between two or three sections of leaves of hyperaccumulators and non-hyperaccumulators. Only one of these experiments showed statistically significant results, i.e non-hyperaccumulating *Senecio coronatus* material was chosen in preference to hyperaccumulating *Berkheya coddii*. On the basis of all seven experiments, however, it is concluded that hyperaccumulation of nickel does not reduce herbivory by slugs.

## **THE SERPENTINE FLORA OF CUBA : ITS DIVERSITY**

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The Cuban serpentine flora is the third richest in the world ; it is formed by 920 species and it makes up 15% of the whole Cuban flora (6200 species).

This group of species is distributed in 12 outcrops of serpentine soils in a longitudinal axis (W-E) along the island; these areas differ from one another with respect to size, age, evolution, orography, soil types and climate; these features contribute to increase the plant diversity.

In this communication the author shows the endemism (paleo- and neoendemism), geographical distribution, floristic composition and conservation degree of the rich Cuban serpentine flora.



## NI-ACCUMULATING PLANTS IN THE SERPENTINE FLORA OF CUBA

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Recent studies and analytical work in leaf samples from part of the very large Cuban serpentine flora has revealed that 22 species are Ni-accumulators (100-1000  $\mu\text{g/g}$  dry mass) and 86 species are Ni-hyperaccumulators ( $> 1000 \mu\text{g/g}$  dry mass) ; it represents 2,3% and 9,3% respectively of all the endemic serpentine species (920 species). The floristic composition is ; accumulators : 12 families, 17 genera, 22 species; hyperaccumulators : 6 families, 16 genera, 86 species (4 families have both types). The families and genera with most Ni-accumulating species are : Asteraceae (*Pentacalia*, *Senecio*), Buxaceae (*Buxus*), Euphorbiaceae (*Leucocroton*, *Phyllanthus*).

There is a close relationship between the paleoendemic species and Ni-accumulating plants because the majority of these (91 species) grow in the "older" serpentine soils ; while a small quantity grows in "younger" soils and others in both soils.

Further analyses will reveal more Ni-accumulating species; the information given in this paper shows that Cuba has the largest number of Ni-accumulating plants yet founded in any one country.

## WEATHERING OF SERPENTINITE ROCK : LABORATORY SIMULATION

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It is well known from literature, that the weathering of the parent material by biota is of fundamental importance in the first phases of soil formation. Pioneer plants may cause the weathering of the rocks and the release of nutritive elements. They act as a sink of elements from the silicate structure, thus decreasing the concentration of the solution, and they emit organic acids that decrease locally the pH in the rhizosphere. The latter mechanism may also be caused by the microbes associated with higher plants.

The aim of this work was the evaluation of the release of elements from a serpentinite rock subjected to *in vitro* weathering with organic acids. The serpentinite was collected in North-Western Italy (Valle Erro, Liguria) and its chemical composition is as follows : SiO<sub>2</sub>:42.07; MgO: 41.73; Al<sub>2</sub>O<sub>3</sub>: 0.81, Fe<sub>2</sub> O<sub>3</sub>: 6.07, NiO: 0.32; CaO: 0.14. From a mineralogical point of view, we found chrysotile, antigorite and small amounts of magnetite, talc, amphiboles, magnesites and magnesium chromites to be present. The rock was crushed and sieved and the fraction between 2 and 425 µm was shaken with H<sub>2</sub>O, HCl, lactic, oxalic and acetic acids (pH 3). The maximum time of shaking was 1024 hours and in the solution we measured Si, Mg, Al, Fe, Ni, Cr, Ca, K, Na, Mn. The weathered rock was analysed by XRD. The surface area and the changes in the distribution of particle sizes was also evaluated.

The effectiveness of the extractants and their weathering ability was highly variable depending on the element probably because of the mechanism of action, on the final pH and on the structural position of the cation. The oxalic acid was proved to be the most effective one towards almost all elements, probably because of this complexing ability.

## THE ULTRAMAFIC VEGETATION OF TUSCANY, ITALY, GEOBOTANICAL KNOWLEDGE AND CONSERVATION

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Flora and vegetation of Tuscan ultramafics are well known, since botanical studies are available from the sixteenth century (CESALPINO, 1583, *The plantis Libris*) and are still undergoing. Research presently concerns ecophysiology of serpentine plants and vegetation ecology. The present contribution focuses on the state of the art of the geobotanical knowledge and the main problems of vegetation conservation.

The most typical vegetation type is an endemic garigue community which grows, differentiated into two subassociations, in almost all the Tuscan ultramafic outcrops (CHIARUCCI *et al*, 1995, *Webbia*, 49 : 179-192) and is characterized by low species richness but also the presence of several endemics. The occurrence of taxonomically interesting and probably undescribed taxa in this vegetation type is discussed. Woody coenoses, reported in several areas, grow almost exclusively in sites with special pedo-morphological characters and do not show any « serpentine » features. Pinewoods of human origin are largely diffused and are often destroyed by fires.

As far as the conservation of the typical vegetation is concerned, it has been recently pointed out that pine afforestations cause marked modifications in the typical garigues (CHIARUCCI & DE DOMINICIS, 1995, *Isr. J. Plant Sci*, 43: 7-20), leading to the disappearance of the endemic and the spread of several alien species. An enrichment of exchangeable soil metal content, positively related to the organic matter provided by the pine canopies, was also found, but it does not seem to affect species richness. Several caving activities are also diffused on ultramafic areas and cause marked changes in natural landscape and vegetation.

To preserve the special plant communities as well the typical bare landscape, a management aiming at the rehabilitation of the mining areas and the reduction of pinewoods is recommended. Finally, some serpentine plants should probably be reintroduced in small ultramafic outcrops which are completely covered by pinewood.

## THE RED HILLS OF CALIFORNIA : ECOSYSTEM PROTECTION AND LAND USE

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Federal, state, and local government agencies have developed a cooperative management program for The Red Hills, a serpentine ecosystem located in the lower foothills of the Sierra Nevada mountain range of California. This multi-jurisdictional plan manages for ecosystem protection in the context of multiple other demands for uses of the land. Recreation is an important activity on the public land ; on private land, development is a major use. Grazing and mining are also regulated uses on both public and private lands.

The unique geology and ecology of the area support a variety of serpentine communities. Of particular interest are two distinct chaparral communities, buckbrush-digger pine and toyon-manzanita, and a riparian community. A number of rare serpentine plant species occur in The Red Hills, including *Verbena californica*, which is found only along creek banks and seeps. The State of California has recently listed it as endangered.

## SOME ASPECTS OF NI TOLERANCE IN *ALYSSUM BERTOLONII* DESV. : STRATEGIES OF METAL DISTRIBUTION AND ACCUMULATION

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*Alyssum bertolonii*, endemic to Tuscan serpentine soils, is a well known Ni-hyperaccumulator (1). We have found that in this species Ni is localized especially in the more superficial tissues of the various organs (leaf epidermis and hairs, stem and root cortex). As previously reported (2), in the leaves Ni is associated to high concentrations of malic and malonic acids. In the cellular sap extracts obtained from the leaves and the root cortex and in the xylem fluid, we have fully identified by HPLC and GC-MS a Ni malate complex. This suggests that in this form Ni is accumulated in the root and then transported and selectively accumulated in the leaves. *A. bertolonii*, in comparison to other species growing in the same habitat and therefore subjected to the same selective pressure, shows a higher Ni tolerance which does not depend on the environmental conditions, but most likely on the elevated quantities of Ni accumulated by this plant. The hyperaccumulation of Ni in the more superficial parts of the plant is in accordance with the hypothesis of a protective mechanism against herbivores or pathogens.

(1) Vergnano Gambi O., Gabbrielli R. and Pandolfini T. (1992) In : The Vegetation of Ultramafic (Serpentine) Soils. Intercept, Andover, UK : 319-329

(2) Pelosi P., Fiorentini R. and Galoppini C. (1976) Agr.Biol.Chem. 40(8) : 1641-1642

## MYCORRHIZAE IN A PORTUGUESE SERPENTINE COMMUNITY

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The serpentine soils of NE Portugal are known to have high Ni concentrations, high Mg/Ca ratio and nutrients deficient for plant growth. The vegetation is sparse but rich in species, much of them endemic.

Roots of some species (several herbaceous and one tree) were collected in the field, fixed in ethanol 70% and assessed for mycorrhizal colonization using standard techniques. All plant species examined so far were colonized at some extent by mycorrhizal fungi, except *Alyssum pintodasilvae*, a typical serpentinophyte belonging to the non-mycorrhizal family Brassicaceae and the only nickel hyperaccumulator species. *Festuca brigantina*, *Anthyllis sampaiana*, *Plantago radicata* and *Dianthus marizii* showed arbuscular mycorrhizal (AM) infection. The quantification and identification of endophytes spores isolated from rhizospheric soil is in progress. *Quercus ilex*, the predominant arboreous species in this area was found to have ectomycorrhizal (ECM) infection. The morphology and anatomy of such ectomycorrhizae is described.

## AN INVESTIGATION OF THE ROLE OF DROUGHT RESISTANCE IN SERPENTINE TOLERANCE IN THE *MIMULUS GUTTATUS* COMPLEX

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*Mimulus pardalis* is serpentine endemic of California, whilst *Mimulus guttatus* is a bodenvag species. Initial fieldwork studies indicate large changes in the dominance of these two species over short distance, according to slope position. *M. pardalis* is dominant upslope but declines in density until at the base of the slope *M. guttatus* becomes dominant. This suggests that drought may be of major importance in explaining the distribution of these two species. *M. pardalis* flowers earlier than *M. guttatus*, has narrower and smaller leaves and is smaller and more branched plant; characteristics which are all often associated with drought-avoiding species. We are making a comparative morphological, phenological and physiological investigation of *M. guttatus* and *M. pardalis* to determine characteristics associated with drought resistance. We will report on the responses of gas exchange and plant water relations to water deficit, and also the reponse of photosynthesis at the cellular level.

## **WHAT REVEGETATION METHOD WILL RESTORE THE BIODIVERSITY OF OLD MINE SITES IN NEW CALEDONIA**

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New Caledonia is renowned for its floristic diversity and high level of endemism. Outcrops of ultramafic rock, the origin of nickel ore, cover 1/3 of the Grand Terre (main island) and possess a highly diverse flora (1800 species of phanerogams of which 1150 species are endemic to these outcrops)

Nickel mine revegetation practices in New Caledonia are based on three methods. Site rehabilitation is carried out by either artificially improving substrate conditions, hence favouring exotic species or by implanting several gregarious nitrogen fixing species (Casuarinaceae, Leguminosae), or by establishing a variety of endemic ultramafic colonisers (Cyperaceae, Myrtaceae, Proteaceae ...). These three methods differ in their ability to both restore the biological conditions of the site and reconstitute its original biodiversity. Studies of the natural and secondary vegetation show the possible effects vegetation composition have on restoring the fertility of the underlying soil.

Preliminary results indicate that endemic ultramafic species are slow growing due to the poor nutrient status of the substrate. Many of the species accumulate different plant nutrients. Combining these ultramafic colonisers with nitrogen fixing species may increase the growth and eventual establishment of a diverse endemic flora.



## RÉSISTANCE DES MILIEUX ULTRABASIQUES AUX INVASIONS BIOLOGIQUES : UNE IDÉE FAUSSE ? CAS DES FOURMIS DANS LE GRAND MASSIF SERPENTINIQUE DU SUD DE LA NOUVELLE-CALÉDONIE.

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La grande originalité des conditions édaphiques offertes par les milieux serpentiniques néo-calédoniens ont contribué au développement d'une faune et d'une flore hautement diverse et endémique. Ces conditions sont également responsables pour la flore d'une résistance à l'anthropisation et aux invasions biologiques : il n'y a pas d'implantations durables d'espèces végétales exogènes sans concours de l'homme. A partir des observations botaniques (faible productivité donc faibles ressources trophiques, toxicité d'une partie de la végétation), on a longtemps estimé que les milieux ultrabasiques offraient également une résistance naturelle contre l'envahissement par les espèces pionnières animales.

Toutefois, une étude récente des communautés de fourmis, par pots de Barber ("pitfall traps"), dans le grand massif péridotitique de Sud, a permis de montrer un envahissement aussi bien des zones anthropiques que des maquis ultrabasiques et des forêts denses humides par des fourmis exotiques. Les espèces suivantes ont notamment été rencontrées : *Wasmannia auropunctata*, *Anoplolepis longipes*, *Paratrechina longicornis*, *Tapinoma melanocephalum* et *Pheidole megacephala* (cette dernière uniquement observée pour l'instant en zone anthropique). Or, ce sont toutes des fourmis vagabondes ("tramp species"), reconnues pour leur tendance anthropophile. Pour chacune d'elles, plusieurs travaux dans différentes régions du monde ont déjà souligné leur caractère opportuniste et pionnier ainsi que leur grande agressivité prédatrice, avec tout un cortège de conséquences néfastes pour les faunes natives. Ces observations soulignent la fragilité de ces milieux et l'urgence des mesures de conservation à prendre pour préserver leur extraordinaire biodiversité. Dans la perspective de sélectionner des aires prioritaires à conserver, la structure des communautés de fourmis semble un indice biologique efficace pour qualifier l'intégrité d'un milieu.

**Cu-TOLERANCE AND ACCUMULATION OF TWO POPULATIONS OF *SILENE ARMERIA* L. FROM A COPPER-MINE AND FROM A SERPENTINITE OUTCROP (NORTHERN APENNINES, ITALY)**

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Within a research program on the vegetation ecology of the northern Apennine ultramafic soils (serpentinites, gabbro and diabases), the scree vegetation of two areas was intensively studied in 1994. The former - Mount Prinzera - is a serpentinite representative area and the latter - Vigonzano - includes serpentinites, gabbros and diabases as well as an abandoned copper mine. A survey of the metal accumulation capacity of some plants living in these two areas was performed. A Cu-accumulation ability was observed in *Silene armeria* L. particularly in the copper-mine population. This population exhibits distinctive morphological features and a higher Cu-concentration compared to the serpentinite populations. Cu-tolerance of the *Silene armeria* population from the Vigonzano copper mine area and of the one from the Mount Prinzera was compared. In seedlings treated with increasing Cu external concentration some growth parameters - the root and shoot length and the biomass production - were described. Preliminary results indicate that 20  $\mu\text{M}$  Cu caused a significant reduction of growth and FW/DW ratio in both populations, while the germination rate was not affected.

## ÉTUDE DE BACTÉRIES LIBRES FIXATRICES D'AZOTE ATMOSPHERIQUE ASSOCIÉES AUX PLANTES (GRAMINÉES, LEGUMINEUSES ET CYPÉRACÉES) AFIN DE REVÉGÉTALISER LES TERRAINS MINIERs.

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En analysant les facteurs écologiques relatifs aux terrains miniers, il a été possible de se rendre compte d'un problème important en matière d'environnement : la dégradation des sites miniers consécutive à une action anthropique profonde et irréversible. Pour réhabiliter ces sites, plusieurs solutions peuvent être envisagées : plantation d'espèces autochtones arbustives, arborescentes et/ou herbacées ou introduction d'espèces exogènes périssant au cours des années et laissant la place à terme à des espèces autochtones.

Parmi les espèces herbacées, les meilleurs résultats ont été obtenus avec les Cypéracées endémiques. Cependant, ces espèces ont une implantation et un développement très lents et leurs semences ne sont pas disponibles dans le commerce. Ainsi, les travaux de recherche visent à identifier des associations Graminées/Diazotrophes et Graminées/Diazotrophes/Légumineuses/Rhizobium pour revégétaliser les sites miniers rapidement et à trouver des modèles associatifs Cypéracées/Diazotrophes capables de prendre le relais. Dans cette association plante/diazotrophe libre, le rôle de chacun des partenaires est bien défini et l'intérêt y est réciproque : la bactérie fixe l'azote atmosphérique, se multiplie, libère une hormone de croissance (Acide Indole-3 Acétique) et parallèlement, la plante exsude des molécules carbonées, augmente sa biomasse foliaire, racinaire et ses échanges avec le milieu.

Le protocole expérimental est organisée comme suit :

- Isolement des bactéries associées aux différentes plantes testées ;
- Test de réduction de l'acétylène ( $C_2H_2$ ) en éthylène ( $C_2H_4$ ) par chromatographie en phase gazeuse, destiné à tester l'activité réductrice de la bactérie ;
- Description macro- et microscopique des bactéries pour arriver à l'identification partielle ou totale avec l'aide des galeries API, du Bergey's Manual et si nécessaire grâce à des techniques de biologie moléculaire (P.C.R. et R.F.L.P.).

Les bactéries ainsi retenues constituent la collection-type dont l'association avec les plantes sera étudiée et comparée dans un deuxième temps à celle de diazotrophes de référence (du genre *Azospirillum*) dans les expérimentations à venir.

**NICKEL CONCENTRATIONS AND HERBIVORY IN *STACKHOUSIA TRYONII*, A NICKEL-HYPERACCUMULATING PLANT OF CENTRAL QUEENSLAND, AUSTRALIA : IS THERE SPATIAL AND SEASONAL VARIATION ?**

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Scanning electron microscopy (SEM) offers an exceptional opportunity to investigate the spatial distribution of nickel in an hyperaccumulator plant. Other researchers have demonstrated nickel levels of 1 to 2% in the leaves of *Stackhousia tryonii*, which is endemic to the serpentinite soils of the Port Curtis region in central Queensland. It is the only known hyperaccumulator from eastern Australia. We examined nickel levels at monthly intervals over a year and at two spatial scales : that of individual plants within a single population, and at microsites within single leaves. We used energy dispersive spectroscopy (EDS) for surface microanalysis of the leaf and electron imaging for additional data on the distribution of nickel within the leaf. We discuss our results in light of the several hypotheses that have been proposed regarding the function of high nickel concentrations in plant tissue, our primary interest being in its possible role in antiherbivore defence.

## LA REHABILITATION DES SITES MINIERES EN PROVINCE NORD

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Le Service Forêts - Bois - Environnement (Direction du Développement Rural et de la Pêche - Province Nord) réalise depuis plusieurs années diverses actions en faveur de la protection et de la réhabilitation des sites miniers :

- Conduite d'essais en essences locales : Chêne Gomme et Santal à Tangadiou/Koumac

- Maitrise d'oeuvre pour le compte de sociétés minières : Plantation sur décharge contrôlée et site d'exploitation dans le massif du Kaala à la demande de la SLN.

Production de plants d'espèces minières : Arbustes de différentes espèces.

Conseils techniques : Reverdissement sur mine d'altitude, avis sur plantation et écran paysager, stabilisation de stériles.

Diagnostics de pollution minière : Sur les secteurs de Koumac, Poya, Népoui, Gomen, Monéo,

Ces interventions sur initiative propre à la demande de particuliers, de collectivités publiques ou de mineurs selon le cas, restent relativement localisées dans l'espace et le temps.

Intéressantes, nécessaires et instructives, elles restent toutefois sans commune mesure avec l'étendue et l'ampleur des impacts de l'exploitation minière en Province Nord.

Dans le cadre plus général des milieux serpentiniques, le service forestier provincial participe ou organise des rencontres, visites et recensements concernant leurs formations végétales. Cela concerne plus particulièrement les maquis de piedmont, les localités de *Santal* ou d'*Araucaria*, la flore d'altitude.

## **PALM COMMUNITIES AS A KEY TO FOREST TYPES AND SOILS ON ULTRAMAFIC ROCKS IN SOUTHERN NEW-CALEDONIA**

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The rain forest on ultramafic slopes in the Southern Massif of New Caledonia develops under various soil conditions : eroded peridotites, ferralitic ferritic colluvia and hypermagnesian soil derived from serpentinites.

These soils types frequently occur as a mosaic in the rain forest and some distinctive structural and floristic characters of the forest are associated with each one.

Palms are abundant in the understorey of the forest and are very good indicators of these variations. There is one species typically associated with one type of soil and the structure of the whole palm community (up to 6 species and 3500 plants per ha) gives information about the ecology of the forest, including degree of disturbance.

Within primary rain forests, we can recognize three main palm communities types.

On ferralitic ferritic colluvia, *Cyphokentia macrostachya* Brong. is dominant, with secondly *Basselinia pancheri* (Brong. & Gris) Vieill. and *Brongniartikentia vaginata* (Brong.) Becc.

On eroded peridotites, *Campecarpus fulcitus* (Brong.) Wendl. ex Becc. grows in large number together with *Actinokentia divaricata* (Brong. & Gris) Dammer.

*Campecarpus* is well adapted to this rocky environment, developing long stilt roots between the huge blocks of peridotite. *Actinokentia* is relatively heliophilous and profits by the clearer canopy of these forests.

On serpentinite, the palm community is dominated by *Burretiokentia sp nov.*, which is restricted to soils rich in magnesium, and *Chambeyronia macrocarpa* (Brong.) Vieill. ex Becc. Within secondary forest types, either mixed or monodominant, the same pattern of palm community is observed, with *Basselinia pancheri*, *Actinokentia divaricata* and/or *Brongniartikentia vaginata*.

## **POPULATION DYNAMICS OF *ARAUCARIA LAUBENFELSII* ON MONT DO, NEW CALEDONIA**

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Many of the southern hemisphere conifers occur as emergent trees in high diversity angiosperm forests. Their regeneration status within such forests has been the subject of much controversy and debate over the past 40 years. This study examines the regeneration ecology of the New Caledonia conifer, *Araucaria laubenfelsii*, which occurs as an emergent tree both in closed forest and in a unique structural association with maquis vegetation on ultramafic soils. Three sets of hypotheses are addressed, focusing on ; the processes which create and maintain the unique structure of the maquis-conifer community, the stand dynamics of these conifers within closed forest, and the spatial and temporal stability of the maquis-forest boundary along varying substrates. Conifer establishment, growth, survival and reproduction is currently being traced in permanent plots, and age structures, stand histories and fire frequencies are in the process of being reconstructed using tree-rings. Boundary dynamics data are being collected and investigated using belt transects.

## REVEGETATION IN THE SURROUNDINGS OF CHILEAN COPPER SMELTERS

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The high environmental risk of the contamination with heavy metals lies in both high toxicity indices and their lengthy permanence in soils - basic resource for food production and for environmental equilibrium.

Decontamination of soils with heavy metals can be carried out through living organisms which inevitably interact with various environmental pollutants.

An example of the above is that certain native plants grow in metalliferous soils, thus developing a capacity to bioaccumulate metals. This characteristic of hyperaccumulating plants can be used for the recovery of soils contaminated with heavy metals.

The present study puts forward a method for researching plants and analyses its feasibility to decontaminate soils affected by the metallurgical industry.



## SOILS AND PLANT NUTRITION ON A SERPENTINIZED RIDGE IN SOUTH GERMANY

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The soil association is described for a serpentinized ridge and its adjacent upper slopes in Northeastern Bavaria (Germany). On gentle and moderately inclined parts of the relief medium to deeply weathered Eutric Cambisols dominate. Specific properties are the unusually high Mg saturation values (35-85 %) and Mg/Ca (exchangeable) quotients (1.6 - 10.8) in the mineral soil horizons. Steeper parts of the slopes are characterized by Rego-Eutric Cambisols and Eutric Regosols. Eutric Leptosols dominate the footslope of a quarry.

The supposed formation of Mg  $(\text{HCO}_3)_2$  and Mg  $(\text{OH})_2$  by carbonic acid influence and hydrolysis respectively and the ability to an exchange-buffering by Mg help maintain a high soil pH. i.e.: (6.5) in the Cv horizon. The formation of an organic floor humus after establishment of a coniferous forest on former grassland was certainly an additional reason for the top soil acidification on Mg leaching. The binding strength of Mg at humic exchange places is lower than that of Ca; the relatively high Ca concentrations and the Mg/Ca quotient  $< 1$  in the organic horizons (O) of the profiles no.2 and 3 were probably caused by the biological Ca cycle as well as by the selectivity of the exchanger for that cation.

The weathering of serpentine and loess caused an accumulation of clay minerals and Fe-oxides/hydroxides, however illuvial clay cutans were not observed on the surface of soil aggregates in the B-horizons and the potential clay migration during a pH stage of 5.0-6.5 may have been prevented by elevated concentrations of coagulating Fe-ions or cementing Fe-oxides.

The macro-nutrient and heavy metal concentrations in the leaves of characteristic herbaceous species growing on different soil types of the same serpentinized ridge were also investigated. *Cerastium holosteoides* exhibited extremely high Mg, Fe, Ni (824-951  $\mu\text{g g}^{-1}$ ) and Cr levels on a virgin serpentine soil; *Silene vulgaris* was characterized compared to it by a restricted accumulation of those elements. *Deschampsia flexuosa* which showed the lowest Mg and Ni concentrations of the investigated species on more developed soils had much higher Cr levels than intraspecific populations on nonserpentinized forest soils.

The predominance of members of the Caryophyllaceae family (genera *Silene* and *Cerastium*) in the pioneer vegetation of the pure serpentinic colluvium soil (profile no.1) is a general feature of many immature serpentine soils elsewhere and here. Members of this family seem to be well adapted to a low interior Ca-concentration and an excess of magnesium and heavy metals like Ni and Cr. High levels of water soluble oxalate in the leaves may cause a precipitation of Mg and possibly also a complexation of heavy metals. Nevertheless the data of tissue analysis in this paper indicate an evolution of quite different mechanisms of adaptation. *Cerastium holosteoides* extremely accumulated Mg, Fe, Ni and Cr in the leaves; the detoxification of these elements was probably promoted by the efficient Ca uptake.