Sixth International Conference on Serpentine Ecology

College of the Atlantic
Bar Harbor, Maine, USA

June 16-23, 2008

ORGANIZING COMMITTEE

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Mr. Ted Koffman - Director of Government Relations and Summer Programs, College of the Atlantic, ME, USA

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WELCOME NOTE

On behalf of the Organizing and Scientific Advisory Committees, I welcome you to the Sixth International Conference on Serpentine Ecology at College of the Atlantic (COA), Bar Harbor, Maine, USA. Since 1991, "serpentinophiles" have met every 2-4 years to share their fascination with serpentinized habitats from around the world. The research highlighted ranges from geology to ecology, and the inter-disciplinary nature of the research attracts a wide range of researchers along with many amateur naturalists. These conferences are educational and, at the same time, enjoyable experiences for everyone involved.

It is my pleasure to announce that this is the largest gathering of "serpentinophiles" to date. The Sixth International Conference has attracted 93 delegates from 21 countries. The countries along with the number of delegates are: Albania (2), Australia (7), Bulgaria (1), Canada (3), Czech Republic (1), Cuba (2), France (2), India (2), Iran (2), Italy (4), Japan (4), Morocco (1), New Caledonia (4), New Zealand (2), Portugal (2), Russia (3), South Africa (1), Spain (1), Sri Lanka (2), UK (1), USA (46). The Conference will highlight 51 Oral Presentations and 35 Poster Presentations on topics under the themes *Geology and Soils*, *Biota*, *Ecology and Evolution*, *Physiology and Genetics* and *Applied Ecology*. We thank you for your participation and welcome you to the truly international family of "serpentinophiles."

I would like to take this opportunity to thank several individuals for their extraordinary efforts in organizing this Conference. I want to acknowledge the efforts of Ms. Jean Sylvia, Assistant Director of Summer Programs and Conference Secretary; without her involvement we would not have been able to put this Conference together. She and her devoted student assistants, Madeline Helser, Brett Ciccotelli, Mariah Levine, Josie Rassat, Emily Postman and Adelina Mkami, have worked long hours over the last several months attending to everything that has made this Conference possible. I also want to thank COA President David Hales and Mr. Ted Koffman, Director of Government Relations and Summer Programs (COA), along with the students, staff, faculty, and trustees of the college for their support in bringing the Conference to the beautiful campus at COA. Finally, my thanks to Elizabeth Battles Newlin Chair in Botany (COA), Maine Space Grant Consortium (NASA), and Barrick Gold of North America for providing financial assistance.

I look forward to a productive week of professional and personal exchanges.

Nishanta "Nishi" Rajakaruna
Chief-Organizer
Sixth International Conference on Serpentine Ecology

Program

Sunday June 15, 2008 – Arrival

5:30-7:00: BUFFET DINNER (KAELBER HALL)

8:00-8:30: Documentary by Megan Erskine: *Fifth International Conference on Serpentine Ecology, Siena, Italy* (Gates Auditorium)

Day 1 – Monday June 16, 2008

7:00-8:00: BREAKFAST

INTRODUCTORY COMMENTS (GATES AUDITORIUM)

8:15-8:25: *Introduction and Welcome* – Alan J.M. Baker

8:25-8:35: *Welcome* – David Hales, President, College of the Atlantic

8:35-8:55: *The International Conferences on Serpentine Ecology: A retrospective* – Robert S. Boyd

SESSION: *GEOLOGY & SOILS*

9:00-9:20: 001. *Serpentine Geoecology of the Appalachian Orogeny* – Earl B. Alexander

9:20-9:40: 002. *Alkaline Seeps and their importance in Serpentinized Areas, Western Newfoundland, Canada* – Bruce A. Roberts & K.W. Deering

9:40-10:00: 003. *Serpentinizing Fluids Craft Microbial Habitat: Using Geochemistry and Thermodynamics to Identify Metabolic Niches in the Subsurfac*e – Dawn Cardace & Tori M. Hoehler

10:00-10:20: 004. *Heavy Metals and their Effects on Biological Activity in Subalpine Soils on Serpentinite* (*Western Italian Alps*) – M.E.D'Amico, F. Calabrese, A. Rossetti & F. Previtali

10:20-10:40: COFFEE/TEA BREAK

10:45-11:05: 005. *Pedogenesis and Nickel Availability for Hyperaccumulators in an Albanian Ultramafic Toposequence* – Guillaume Echevarria, A. Bani, E. Montargãs-Pelletier, S. Sulçe & J. L. Morel

11:05-11:25: 006. *Physical and Chemical Properties of Ultramafic Soils across Environmental Gradients in Susúa State Forest, Puerto Rico* – Jamie L. Horvath & Arthur H. Johnson

11:25-11:45: 007. *Seasonal Changes in Nickel Concentration of Soil and Stream Water in Three Forests on Ultramafic Sites in North Carolina and Puerto Rico* – Joe Pollard, Caroljane Roberson, Heather Stewart, Sarah Crosby, Kartikeya Singh, Kelly Wilson, Solimar Marrero & Eva Dávila

11:45-12:05: 008. *Did New Caledonian Uplift Cause Antarctic Glaciation?* – Douglas N. Reusch

12:05-1:10: LUNCH

1:15-1:35: 086. *Biogeochemistry of a forest watershed underlain by serpentine in central Europe* – P. Kram, J. Hruska, F. Oulehle, V. Stedra, J. B. Shanley, & R. Minocha

SESSION: *BIOTA*

1:35-1:55: 012. *Is there a Serpentine Ectomycorrhizal Community?* – Sara Branco

1:55-2:15: 013. *California Ultramafic Chaparrals: A Phytosociological Approach* – D. Sánchez-Mata & M.G. Barbour

2:15-2:35: 014. *Geobotany and Biogeochemistry of the Ultramafic Soils of Neyriz, South of Iran* – S.M. Ghaderian, H. Fatahi & A.R. Khosravi

2:35-2:55: 015. *The Phytosociological System of the Cuban Serpentine Flora* – R. Berazaín Iturralde & L.R. González-Torres

2:55-3:15: 016. *Floral Diversity and Conservation of the Ussangoda Serpentine Site in Sri Lanka* –Y.A.S. Samithri, D.S.A. Wijesundera & M.C.M. Iqbal

3:15-3:35: COFFEE/TEA BREAK

3:40-4:00: 017. *Ecological Studies on the Endemic Cerastium utriense* (*Caryophyllaceae*) – S. Marsili, E. Roccotiello, I. Rellini, G. Barberis & M.G. Mariotti

4:00-4:20: 018. *Analysis of Physicochemical Properties, Soil Biota and Heavy Metals in the Serpentinite Mining Area of Southern Rajasthan (India)* – Nidhi Rai & Giriraj K. Songara

4:30-5:30: WELCOME DINNER

5:45-9:00: SCHOONER RIDE

Day 2 – Tuesday June 17, 2008

7:00-8:00: BREAKFAST

SESSION: *BIOTA, CONTINUED*

8:30-8:50: 019. *Flora of the New Idria Serpentine Mass* (*California, USA*) – Ryan O'Dell

8:50-9:10: 020. *The Nickel Hyperaccumulating Plants of the Serpentines of Turkey and Adjacent Areas* – R.D. Reeves & N. Adıgüzel

9:10-9:30: 021. *Geoecology of Serpentine in Eastern North America: Critical Information Gaps and Future Directions* – Nishanta Rajakaruna, Tanner B. Harris & E.B. Alexander

9:30-9:50: 022. *Serpentine and Nonserpentine Ecotypes of Collinsia sparsiflora Associate with Distinct Arbuscular Mycorrhizal Fungi Assemblages* – Shannon P. Schechter & Tom D. Bruns

9:50-10:10: 023. *Soil and Vegetation Heterogeneity on a Serpentine Site in Ussangoda, Sri Lanka* – H. Asiri S. Weerasinghe, S. Madawala Weerasinghe, G.W.A.R. Fernando & M.C.M. Iqbal

10:10-10:30: **COFFEE/TEA BREAK**

10:35-10:55: 024. *Lichen Flora of Serpentine in the Middle Urals of Russia* – Alexander Paukov

10:55-11:15: 025. *Plant Diversity and Vegetation of Ultramafic Rocks in The Middle Urals of Russia* – A. Teptina

11:15-11:35: 026. *Ecology of the Serpentines of Tien Shan* – V.N. Dolzhenko

11:35-11:55: 027. *Special Ultramafic Vegetation of the Glaciated Appalachian Québec Reentrant* (*Eastern Townships, Canada*) – Geoffrey Hall

12:00-1:00: **LUNCH**

SESSION: *ECOLOGY & EVOLUTION*

1:15-1:35: 041. *A Predictable Evolutionary Pathway to Serpentine Endemism and its Consequences in the California Flora* – Brian Anacker, Justen B. Whittall & Susan P. Harrison

1:35-1:55: 042. *Oaks on and off Serpentine: Ecotypic Variation and the Role of Mycorrhizal Fungi for Plant Growth* – Sara Branco

1:55-2:15: 043. *Nickel Hyperaccumulators Mobilize Nickel into New Caledonian Epiphytes* – Robert S. Boyd, Michael A. Wall & Tanguy Jaffré

2:15-2:35: 044. *Testing Soil Nutrients and Plant Genotypic in Serpentine Plant – Soil Interactions* – Danny J. Gustafson

2:35-2:55: 045. *Extending the Elemental Defense Hypothesis: Low Levels of Nickel May Defend Serpentine Mimulus guttatus from Herbivory* – Sarah E. Dalrymple, Robert S. Boyd & Micky D. Eubanks

2:55-3:15: 046. *Evidence of Adaptive Tolerance to Nickel in Serpentine Isolates of the Ectomycorrhizal Fungus Cenococcum Geophilum* – Susana C. Gonçalves, M. Amélia Martins-Loução & Helena Freitas

3:15-3:35: 047. *Ecotypic Variation in Morphology and Elemental Concentrations in the Californian Ni Hyperaccumulator Strepthanthus Polygaloides (Brassicaceae)* – Robert S. Boyd & Micheal A. Davis

3:35-3:55: **COFFEE/TEA BREAK**

4:00-6:00: POSTER SESSION (BLUM GALLERY)

6:00-7:00: **DINNER**

Day 3 – Wednesday June 18, 2008

7:00-8:00: **BREAKFAST** (LUNCH BOX PICK UP)

8:30: MID-CONFERENCE TOUR: Meet at the Whale Skull for the Mid-Conference Tour to the Deer Isle Complex, Maine

3:00-4:00: Return to COA

4:00: **DINNER** (explore the many restaurants of downtown Bar Harbor) – 10 minute walk

Day 4, – Thursday June 19, 2008

7:00-8:00: **BREAKFAST**

8:30-8:50: 048. *The Effect of Fire on Serpentine Plant Communities at Sierra Alta De Agabama, Villa Clara, Cuba* – L.R. González-Torres

8:50-9:10: 049. *Parallel Evolution and Convergent Physiological Tolerance Mechanisms of Serpentine-Tolerant Achillea millefolium (Asteraceae) Edaphic Ecotypes* – Ryan O'Dell & Vic Claassen

9:10-9:30: 050. *Climate Change and Serpentine Plants: A Conceptual Framework* – Susan P. Harrison & Ellen I. Damschen

9:30-9:50: 051. *Have 55 Years of Climate Change Affected Serpentine and Nonserpentine Plant Communities Differently?* – Ellen I. Damschen & Susan P. Harrison

9:50-10:10: 052. *Phylogenetic Analysis of the Infraspecific Taxa, Erigeron thunbergii , Distributed in Ultramafic Rock Sites* – Daiju Kawase, Takakazu Yumoto, Kazuhiko Hayashi & Ken Sato

10:10-10:25: **COFFEE/TEA BREAK**

10:30-10:50: 053. *Soil Nickel Influences Survivorship, Growth and Reproduction of the Serpentine Hyperaccumulator Species, Alyssum murale Waldst & Kit.* (*Brassicaceae*) – Mary A Mckenna, Tyra Pendergrass, Iman Sylvain & Monica Arienzo

SESSION: *PHYSIOLOGY & GENETICS*

10:50-11:10: 061. *Localisation of Nickel in Tissues of Streptanthus polygaloides Gray (Brassicaceae), An Endemic Californian Nickel Hyperaccumulator* – V. De La Fuente, D. Sánchez-Mata, L. Rufo, N. Rodríguez & R. Amils

11:10-11:30: 062. *Comparison of Ni-Elimination Strategies in Representatives of Two Families of Beetles Feeding on the Ni-Hyperaccumulating Plant Berkheya coddii* – J. Mesjasz-Przybyłowicz, P. Migula, W.J. Przybyłowicz1, E. Głowacka, M. Rost-Roszkowska, J. Klag, E. Orlowska, M. Augustyniak, M. Nakonieczny & M. Tarnawska

11:30-11:50: 063. Serpentinomics—An Exciting New Field of Study – Jessica W. Wright & Justen B. Whittall

11:50-12:10: 064. *Characterizing Serpentine Tolerance in Mimulus guttatus* (*Phrymaceae*) – Margaret Hendrick

12:15-1:15: **LUNCH**

1:25-1:45: 065. *Cellular Localization and Discrimination of Cobalt and Nickel in Haumaniastrum robertii, Crotalaria cobalticola and Alyssum murale Using Micropixe Spectrometry* – Y.D. Wang, R. Siegele, J.A.C. Smith & A.J.M. Baker

1:45-2:05: 066. *Ni^{2+} Requirement of Alyssum Species Supplied Urea-N.* – Rufus L. Chaney, Guido Fellet, Ramon Torres, Luca Marchiol, Tiziana Centofanti & Carrie E. Green

SESSION: *APPLIED ECOLOGY*

2:05-2:15: 076. *Improving the Agronomy of Alyssum murale for Phytomining in Albania* – Aida Bani, Guillaume Echevarria, Sulejman Sulçe & Jean Louis Morel

2:15-2:35: 077. *Arbuscular Mycorrhizal Fungi from New Caledonian Ultramafic Soils Improve the Tolerance to Nickel of Endemic Plant Species* – Hamid Amir & Alexandre Lagrange

2:35-2:55: 078. *Plant Colonization Limits The Fibre Dispersion in an Abandoned Asbestos Mine* – Sergio E. Favero-Longo, Enrica Matteucci & Consolata Siniscalco

3:00-3:20: **COFFEE/TEA BREAK**

3:25-3:45: 079. *Serpentine Revegetation Concepts* – Ryan O'Dell & Vic Claassen

3:45-4:05: 080. *Restoration of Indigenous Vegetation at Soldiers Delight Serpentine "Barren" in the Mid-Atlantic Piedmont of the United States* – R. Wayne Tyndall

4:05-4:25: 081. *Fire and Ultramafic Vegetation in Northern California* – Hugh Safford

4:25-4:45: 082. *Global Conservation of Serpentine Ecosystems: A Call for Action* – Marla S. Mcintosh

4:45-5:15: Conclusions & Proposals for Hosting the Seventh International Conference – Alan J.M. Baker & Roger Reeves (Moderators)

5:30-6:00: WINE & HORS D'OEUVRES
6:00: BANQUET DINNER

Days 5-8 – June 20-23, 2008

Friday – JUNE 20, 2008:

7:00-8:00: **BREAKFAST** (LUNCH BOX PICK UP)

8:00: POST-CONFERENCE TOUR: Meet at Whale Skull for departure to Gaspé Peninsula, Canada

Monday – JUNE 23, 2008:

6:00-8:00pm: Return to COA

ABSTRACTS

THE INTERNATIONAL CONFERENCES ON SERPENTINE ECOLOGY: A RETROSPECTIVE

ROBERT S. BOYD

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Serpentine environments have fascinated researchers from many scientific disciplines but their results have often been widely scattered among journals. In 1991, a group of "serpentinophiles" organized the First International Conference on Serpentine Ecology, held at UC Davis in California. Since then conferences have been held in New Caledonia (1995), South Africa (1999), Cuba (2003) and Italy (2006). Besides allowing for productive scientific discussions, these gatherings have highlighted some of the cultural and social customs of the host countries. The meetings also have involved field trips to fascinating examples of serpentine habitats, especially during pre- or post-conference expeditions. This retrospective briefly revisits each of the prior serpentine conferences as a prelude to this sixth conference.

SESSION: *GEOLOGY & SOILS*

MODERATOR: ROGER D. REEVES

VISITING PROFESSOR, SCHOOL OF BOTANY, UNIVERSITY OF MELBOURNE, MELBOURNE, AUSTRALIA

ORAL PRESENTATIONS

001. SERPENTINE GEOECOLOGY OF THE APPALACHIAN OROGENY

EARL B. ALEXANDER

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The Appalachian orogen is a belt of deformed terranes stretching southwest from Newfoundland

to Alabama and may be assumed to include terranes of the Quachita orogen that are exposed discontinuously west of Alabama into Arkansas, Oklahoma, and Texas. Terranes of the Appalachian orogen were thrust over the Grenville Province of the North American continent or attached to the continent during the Paleozoic Era. Ultramafic rocks are widely distributed, but sparse, in the accreted terranes of the Appalachian orogenic belt. They have distinctive soils and vegetation. The serpentine soils range from very cold Entisols (Regosols) and wet Mollisols (Gleysols) through cold Inceptisols (Cambisols) to cold and warm Alfisols (Luvisols with argillic horizons and Acrisols with kandic horizons). The serpentine plant communities are commonly less densely vegetated with woody plants than associated nonserpentine communities. Many of the plants are rare species or are present only in serpentine habitats. A presentation of the geological framework and other abiotic aspects of geoecosystems is followed by an integrated presentation of the geological and biological aspects that emphasizes soils and their vegetative cover.

002. ALKALINE SEEPS AND THEIR IMPORTANCE IN SERPENTINIZED AREAS, WESTERN NEWFOUNDLAND, CANADA

B.A. ROBERTS[1] & K.W. DEERING[2]

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The major stress factors related to the plant ecology of areas with serpentinized rocks and soils in Newfoundland are both chemical (low essential nutrients, especially calcium, and toxic amounts of magnesium and nickel) and physical (drought, wind, erosion and cryoturbation). The impoverished but botanically interesting vegetation (Roberts & Proctor 1992, Kluwer Academic Publishers, The Netherlands) in some Newfoundland sites owe much of their plant cover to the presence of alkaline seeps which contribute elevated levels of soluble calcium to offset other various toxic effects. The chemical properties of leachate sampled with porous cup lysimeters from the Tablelands in Western Newfoundland are reported. Three substrate characteristics were compared in three types of substrate [typical barren Regosols (BR) derived from glacial till and colluvium without travertine & seep influence; shallow organic fens (OF) over till and colluvium; and active alkaline seep areas (AS)]. Leachate from BR had a pH range of 7-8, a 5-35 Mg/Ca quotient, with most N as Nitrate (0.2-0.5 ppm). Leachate from OF had a pH range of 6.5-7.5, a 5-40 Mg/Ca quotient, with most N as Ammonia (0.05-0.2ppm). Leachate from AS 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). Periodic erosion in the form of overland flow on steep slopes and cryoturbation in early spring and late fall are the mechanisms which deliver and mix the travertine, but soil leachate below active and non active seeps also provides the important available Ca^{2+} in solution.

003. SERPENTINIZING FLUIDS CRAFT MICROBIAL HABITAT: USING GEOCHEMISTRY AND THERMODYNAMICS TO IDENTIFY METABOLIC NICHES IN THE SUBSURFACE

DAWN CARDACE & TORI M. HOEHLER

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Hydrogen produced by serpentinization has the potential to fuel subsurface microbial metabolisms. In such habitats, the solids comprise ultramafic parent rocks derived from the Earth's mantle, serpentine minerals, veins of hydroxides, and accessory magnetite and/or other metal-rich grains. Fluid that occurs with these solids is altered, trapped seawater and/or meteoric water. It is ultrabasic, with a pH of ~10.5 to 12.1, dominated by Ca^{2+} of 5 to 80 mg L^{-1} and OH^- of 6 to 70 mg L^{-1} (Barnes et al. 1967). The fluid is predicted to be reducing; hydrogen, a powerful reducing agent, is generated when Fe^{2+} in $Fe(OH)_2$ is oxidized to magnetite, coupled to the reduction of water. At submarine serpentinizing seeps, $H_{2(aq)}$ has been observed in the range of 1 to 15 mM (Kelley et al. 2005), and experimental results show the closed system reaction of peridotite and aqueous fluids can produce up to ~75mM $H_{2(aq)}$ (Seyfried et al. 2007). Fluids from seeps on land may contain tens of mM $H_{2(aq)}$ (Sleep et al. 2004), though empirical data are few. $H_{2(aq)}$ has the potential to drive a variety of metabolic processes in oxygen- and organic carbon-deprived environments, which are key to exploring the metabolic landscape at the limits of the deep biosphere. Based on empirical parameters, we have modeled the free energy change for an array of metabolic reactions that may be associated with serpentinization and find that metabolic niches do exist for methanogenesis, ferric iron, sulfate, and nitrate reduction reactions under the $H_{2(aq)}$ activities considered.

004. HEAVY METALS AND THEIR EFFECTS ON BIOLOGICAL ACTIVITY IN SUBALPINE SOILS ON SERPENTINITE (WESTERN ITALIAN ALPS)

M.E. D'AMICO, F. CALABRESE, A. ROSSETTI & F. PREVITALI

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Ultramafic soils are colonized by peculiar plant communities and species adapted to high metal contents, but metal speciation, microbial and arthropodal communities have been scarcely studied, particularly under coniferous forests in boreal or subalpine areas. The high acidity and humidity of these habitats make heavy metals potentially highly mobile and bioavailable. Six subalpine soils, in the ophiolitic area of Mont Avic Natural Park in the Western Italian Alps were sampled and analyzed in order to understand the effects of their chemistry on biological (BSQ

method, based on microarthropodal communities) and microbiological activity (microbial biomass, respiration and derived stress indexes). Five of these soils show strong signs of podzolization and are developed from till composed of mafic and ultramafic materials in different amounts, while the sixth is developed on polluted mine debris. They all have high metal content, high acidity and high metal bioavailability, shown by the chemical speciation; despite the young age of the soils, up to 50% of metals are localized with pedogenic iron oxides and organic matter. These edaphic characteristics deeply influence the arthropodal communities and microbial activity; on metal-rich serpentinite soils, microarthropodal communities are impoverished in biodiversity and in exigent euedaphic forms, while the microbial activity indexes (microbial biomass, respiration, qCO2, TOC/biomass) show the existence of important stress factors. All biological properties are linearly related with available Ni, Co and Mn**.**

005. PEDOGENESIS AND NICKEL AVAILABILITY FOR HYPERACCUMULATORS IN AN ALBANIAN ULTRAMAFIC TOPOSEQUENCE

GUILLAUME ECHEVARRIA[2], AIDA BANI[1, 2], EMMANUELLE MONTARGÃS-PELLETIER[3], SULEJMAN SULÇE[1] & JEAN LOUIS MOREL[2]

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A serpentinized peridotite outcrop located in Pojska (Albania) hosts two of the Albanian Ni-hyperaccumulator species (*Alyssum murale, Thlaspi ochroleucum*). The aim of this study was to relate the variability of Ni bioavailability along the ultramafic toposequence to pedogenesis and consequent soil mineralogy. Hypermagnesic Hypereutric Cambisols dominate upslope and Hypermagnesic Cambic Vertisols occur downslope. The minerals identified varied from primary to secondary phyllosilicates and to Fe oxides. Serpentine, chlorite and smectite (mostly lizardite-antigorite and smectite), were the main minerals occurring in all soils but with different ratios. The highest Ni concentrations were observed in the particles of Mg-rich and Al-poor smectites in the Vertisol (up to 19.5% of Mn), thus reaching 4.9% Ni in weight. Ni was probably sorbed onto amorphous Fe oxides (oxalate-extractable) and was also included in secondary smectites, probably sorbed onto the mineral surfaces or located on internal exchangeable sites (octahedral sites). High Ni availability was confirmed by DTPA extractions and by IEK. However, Ni availability changed along the toposequence, being higher upslope where Ni-bearing amorphous Fe oxides are abundant, and sensibly lower downslope on the Vertisols in which Mg-rich smectites dominate; Ni_{DTPA} varied from 285 mg kg^{-1} in site I (upslope) to 95.9 mg kg^{-1} in site IV (downslope). *Thlaspi ochroleucum* occurred only upslope (0.13 % Ni). Concentration of Ni in *A. murale* shoots was variable from 0.7% upslope to1.4% on downslope. Amazingly, Ni uptake by *A. murale* was negatively correlated to availability, suggesting either the existence of genetic

differences along the toposequence or the existence of specific edaphic conditions that affect the growth of *A. murale* upslope.

006. PHYSICAL AND CHEMICAL PROPERTIES OF ULTRAMAFIC SOILS ACROSS ENVIRONMENTAL GRADIENTS IN SUSÚA STATE FOREST, PUERTO RICO

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Susúa State Forest is located on a belt of ultramafic rocks in southwestern Puerto Rico and has soils that vary in depth and degree of development. We established 50 plots (100 m^2 each) in Susúa over a range of soil depths. In each plot, we collected three soil cores (30 cm) for chemical analysis and dug one quantitative soil pit (0.5 m^2), sampling at 10 cm increments to a depth of 30 cm or bedrock. Soil core pH ranged from 5.55 to 6.98 (median=6.66). Soil texture was a sandy loam for 56% of the plots. The remaining plots also had coarse-textured soils (>30% sand and < 40% clay), which suggests Susúa soils drain rapidly and have poor water holding capacity. Total nitrogen content of the cores averaged 0.35 ± 0.09%; total carbon content averaged 3.97 ± 1.07%. Soil samples from the quantitative pits were analyzed for biologically available metals. Preliminary results from a subset of plots indicate that magnesium (median=51 x 10^3 mg kg^{-1}) and aluminum (25 x 10^3 mg kg^{-1}) are the most abundant metals in the soil. Calcium (12 x 10^3 mg kg^{-1}) is moderately abundant, followed by chromium, nickel (5 x 10^3 mg kg^{-1} each) and manganese (3 x 10^3 mg kg^{-1}). Potassium, phosphorus, zinc, copper, lead, and cadmium all have concentrations < 1000 mg kg^{-1}. The concentrations of calcium, potassium, and phosphorus tend to decrease with depth in the soil profile, suggesting that plants in Susúa are likely concentrating desired nutrients in the uppermost soil horizon (0-10 cm) near the root zone.

007. SEASONAL CHANGES IN NICKEL CONCENTRATION OF SOIL AND STREAM WATER IN THREE FORESTS ON ULTRAMAFIC SITES IN NORTH CAROLINA AND PUERTO RICO

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Ultramafic rocks and soils have peculiar chemistry, including low availability of calcium and high concentrations of magnesium and nickel. Our earlier studies showed significant accumulation of nickel in canopy leaves of ultramafic forests in North Carolina and Puerto Rico. The present research attempted to determine whether seasonal variation in weather and leaf fall

affect nickel concentrations in soil and stream water. We sampled soils and water over the course of one year from a temperate deciduous forest (Buck Creek, NC), a dry tropical forest (Susúa, PR), and a humid tropical forest (Maricao, PR). Organic layer (O-horizon) and mineral layer (A-horizon) soils were extracted using 0.5M ammonium acetate. At Buck Creek, nickel availability in A-horizon soils varied little over the year. Nickel in O-horizon samples was generally lower, except during February when a peak of nickel availability was observed, possibly representing nickel release from decaying leaf litter. Elevated nickel in stream water was detected in April, suggesting nickel movement from soil to surface waters. In the dry tropical forest at Susúa, O-horizon soils had consistently lower nickel concentrations than A-horizon soils, with little seasonal variation. In the humid tropical forest at Maricao, there were no significant differences either between collection dates or soil horizons. All water samples from Puerto Rico were below detectable limits for nickel. These findings suggest that the more dramatic weather changes and more strongly deciduous vegetation in North Carolina consequently cause greater seasonal variability in nickel movement in temperate forests.

008. DID NEW CALEDONIAN UPLIFT CAUSE ANTARCTIC GLACIATION?

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The western Pacific island of New Caledonia is well known for its serpentine flora. It is less well known as a potential trigger for the most recent transition, 34 million years ago (Ma), of Earth's climate from a greenhouse to icehouse state. In the long-term carbon cycle, basic and ultrabasic rocks constitute the principal sink for atmospheric carbon dioxide. As a consequence of microcontinent-arc collision, the New Caledonian seafloor emerged above sea level at the end of the Eocene, and a prominent anomaly in the osmium composition of seawater may be linked to the New Caledonian basic and ultrabasic rocks. The onset of Antarctic glaciation in the earliest Oligocene, 34 Ma, has been attributed to a diminished CO_2-forced greenhouse effect. Previous estimates of silicate weathering and related organic carbon burial suggest that New Caledonian carbon sinks were on the order of 1×10^{18} mol CO_2 per million years and sufficiently large to lower global pCO_2. Paleo-channels imaged on the New Caledonian shelf indicate that New Caledonia was significantly larger when first uplifted. Bedrock structures reflect a transition at the time of uplift from compression to regional tension, which would have enabled extensive rock-groundwater interaction. Ironically, during weathering, the low-silica rocks yield large amounts of dissolved silica, a limiting factor in marine organic carbon burial. Hence, the birth of New Caledonia created local opportunities for serpentine flora, and may also have been responsible for the far-reaching biotic turnovers at the Eocene-Oligocene boundary.

086. BIOGEOCHEMISTRY OF A FOREST WATERSHED UNDERLAIN BY SERPENTINE IN CENTRAL EUROPE - PAVEL KRAM *ET AL.* – SEE PAGE **69**

POSTER PRESENTATIONS

009. SOIL AND VEGETATION DIFFERENCES FROM PERIDOTITE TO SERPENTINITE

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Pedologists and ecologists generally lump peridotite and serpentinite together as substrates with similar serpentine soils. A detailed soil survey in which peridotite and serpentinite were separated in mapping revealed appreciable differences in geomorphic and pedologic features between these two types of ultramafic rocks and some vegetation differences. The survey area is in mountainous terrain. Slopes tend to be steeper on peridotite and the soils redder. In the area mapped, there are more Alfisols (Luvisols) on peridotite and more Mollisols (Phaeozems) on serpentinite. Very shallow soils (7% of the area), which are mostly Mollisols and Entisols (Leptosols), are more common on serpentinite. Barrens are commonly fragmental colluvium (talus) on peridotite and erodible, slightly to moderately stony summits and slopes on serpentinite. The greatest vegetation differences from peridotite to serpentinite are on very shallow soils. There are obvious differences in the distributions of shrub and grass species on these soils, with less distinct differences in tree cover. Leather oak (*Quercus durata*) is the predominant shrub on very shallow peridotite soils and buckbrush (*Ceanothus cuneatus*) is predominant on comparable serpentinite soils. Annual fescue (*Vulpia microstachys*) is the dominant grass on very shallow serpentinite soils and is common on shallow serpentinite soils, with perennial fescues (*Festuca* spp.) dominating the grasses on all other soils, including very shallow to shallow peridotite soils.

010. SERPENTINE GEOECOLOGY OF THE SANTA ELENA PENINSULA, COSTA RICA

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About 20,000 hectares of serpentinized peridotite are exposed on the Santa Elena Peninsula in northwestern Costa Rica. It is the only serpentine body exposed on the Pacific side of Central America. The terrain is hilly to mountainous, with elevations from sea level up to 700 m. Shallow Entisols and Inceptisols (Leptosols and Cambisols) are the dominant serpentine soils. The area was once covered by dwarf deciduous forest that has been converted to savanna by burning. Remnants of the dwarf deciduous forest contain many endemic species. The serpentine area is now managed by the Area de Conservación Guanacaste and is protected to allow the

reestablishment of dwarf deciduous forest.

011. GEODIVERSITY AND WOODY ENCROACHMENT AT THE PILOT SERPENTINE BARRENS, MARYLAND

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Afforestation of nearly all of the serpentine barrens of the Mid-Atlantic States has occurred since the mid-twentieth century. The major threat to this ecosystem is the invasion of woody plants, primarily *Juniperus virginiana* and *Pinus virginiana*. The Conowingo Barrens of Pennsylvania and Maryland are no exception. Of the original 50,000 acres of serpentinite lands, only 2500 acres have persisted. The Nature Conservancy in Maryland began active management of relict grasslands and savannahs at the Pilot Serpentine Barrens (PSB) in 1985, yet exotic and invasive plants heavily threaten the Preserve. The most striking of these encroachment consequences include alterations in aboveground biomass and the shift in foliage phenology from C_4 dominated grasslands to evergreen *Pinus* and *Juniperus* forest. At the PSB, remnant grassland areas share a common lithology and geologic structure surrounded by a diversity of mafic/ultramafic rocks. Additionally, depth profiling of nearby shallow forest soils has shown decreasing $\delta^{13}C$ isotopic signatures from -27‰ (0-5 cm depth) to -22‰ (5-10 cm depth) and in the savannah areas $\delta^{13}C$ isotopic signatures from -19‰ (0-5 cm depth) to -17‰ (5-10 cm depth). This data is consistent with the idea of woody encroachment changing light/soil dynamics resulting in a community structure favoring C_3 photosynthesizers. Trace element data for Cr and Ni show an inverse relationship with C:N ratios indicating detachment of the serpentine influence with increasing woody encroachment. Bedrock geodiversity may have given rise to the PSB grassland/savannah historical mosaic, yet woody encroachment may be modifying soil conditions inhibiting restoration efforts.

SESSION: *BIOTA*
MODERATOR: ROBERT S. BOYD

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ORAL PRESENTATIONS

012. IS THERE A SERPENTINE ECTOMYCORRHIZAL COMMUNITY?

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Serpentine soils are extreme environments rich in heavy metals and poor in nutrients that host depauperate plant communities with high rates of endemism. I am investigating whether the symbiotic fungal communities from serpentine forests follow the same patterns seen for plants. I surveyed the ectomycorrhizal (ECM) communities from one serpentine and two non-serpentine oak forests in northeastern Portugal using the rDNA Internal Transcribed Spacer (ITS) region and found enormous diversity. All three forests showed very different, rich communities with very low ITS type overlap. Additionally, sampling of fungi in the same forest in consecutive years showed a tremendous ITS type annual turnover. The pattern of low diversity for plant communities found on serpentine does not seem to hold for ECM fungi and the existence of endemic ECM serpentine species is still unclear. However, the detection of many ITS types restricted to the serpentine forest is an indication of potentially high endemism. A few ITS types were detected in both serpentine and non-serpentine forests, suggesting the existence of plastic species tolerant to both soils. These results document high ECM diversity associated with Mediterranean oak forests. Further investigation is needed to clarify the existence of particular ECM communities specifically associated with serpentine soils and to determine the role of this extreme habitat in the evolutionary history of symbiotic fungi.

013. CALIFORNIA ULTRAMAFIC CHAPARRALS: A PHYTOSOCIOLOGICAL APPROACH

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The utramafic substrates and vegetation in California covers several types of habitats from sea level to high in the mountains. The unusual chemical characteristics of ultramafic habitats are responsible for the rarity category for almost 300 taxa of the California flora. The main vegetation types developing on ultramafic soils include the natural potential vegetation (climactical vegetation) of these areas, namely conifer forests, conifer woodlands, and sclerophyllous chaparrals. Our research throughout California covered more than 10 years of geobotanical works following the latest approaches in Braun-Blanquet vegetation methods. We recognise five ultramafic chaparral-types (associations) with a precise climatic and biogeographical value, specific floristic composition (including rare or sensitive species as characteristic species), and dynamic patterns; all of these are contained within the phytosociological alliance *Quercion duratae* Sánchez-Mata, Barbour and Rodríguez-Rojo (in Rivas-Martínez 1997). These chaparral types can be considered rare and threatened vegetation types in view of their own particular features. We propose the preliminary phytosociological names and territorial ranges for the recognised associations as follows: *Ceanotho jepsonii-Quercetum duratae*: North Coast Ranges, Great Valley; *Arctostaphylo glaucae-Quercetum duratae*: Central Coast Ranges; *Ceanotho albiflori-Quercetum duratae*: Bay Area; *Arctostaphylo viscidae-Quercetum duratae*: Sierra Nevada; *Yucco whipplei-Quercetum duratae*: South Coast Ranges.

014. GEOBOTANY AND BIOGEOCHEMISTRY OF THE ULTRAMAFIC SOILS OF NEYRIZ, SOUTH OF IRAN

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Ultramafic soils cover substantial areas at many locations in Iran. In this study, soils and plants of ultramafic areas of Neyriz (in southern Iran) were collected, identified and analysed for 'serpentine' metals. Soil analysis of total elements indicates that typical total concentrations of Ni, Cr, Co, Mn, Fe, Mg and Ca are about 1250, 200, 293, 1800, 105280, 73000, and 1960 μg g^{-1}.

The concentration of exchangeable Ni in these soils is up to 4.7 μg g^{-1}. During this study, 119 plant species were collected, belonging to 31 families, mostly Asteraceae, Fabaceaeae, Lamiaceae, Apiaceae, Brassicaceae, Boraginaceae, Caryophyllaceae, Polygonaceae and Liliaceae. The number of plants endemic to ultramafic soils of these areas is very low. Analysis of the dry matter of the leaves of all plants collected did not reveal any hyperaccumulator, of Ni or any other 'serpentine' metal. The highest amount of Ni (141 μg g^{-1}) and Co (47 μg g^{-1}) were found in *Rheum ribes*. The highest amount of Cr (76 μg g^{-1}) was measured in *Nepeta glomerolosa*. The Mg/Ca ratio for some plants was high (up to 25). There were no perennial *Alyssum* species (section Odontarrhena) in this ultramafic area. In ultramafics of western parts of Iran, all previously reported Ni-hyperaccumulators have been from this section of *Alyssum*.

015. THE PHYTOSOCIOLOGICAL SYSTEM OF THE CUBAN SERPENTINE FLORA

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The rich and diverse Cuban flora has been organized in a very large phytosociological system with 47 Classes, 56 Orders, 85 Alliances and 185 Associations. Serpentine plant communities are represented in this system in five Classes, seven Orders, 13 Alliances and 32 Associations. However, this system does not include several studies that have described new syntaxa occurring in serpentine outcrops of the middle of the island. In this work, we present an integrated phytosociological system for the serpentine flora. We consider all the studies carried out so far, update the distribution of the associations in the different serpentine outcrops, and point out rich serpentine regions that have been poorly studied (such as those of eastern Cuba).

016. FLORAL DIVERSITY AND CONSERVATION OF THE USSANGODA SERPENTINE SITE IN SRI LANKA

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Ussangoda is one of the five geologically identified serpentine sites in Sri Lanka, located on the southern coast overlooking the Indian Ocean. The site has a deep red color due to the highly lateritic soil and is a popular location for recreation. This extensive plain of approximately 1 km^2 is sparsely populated with <15 plant species from 7 families. All these species are prostrate with reduced leaf size, short internodes and thick extensive root systems confined to the surface soil

layer. Isolated patches of thorny deep-rooted shrubs occupy <5% of the plains. These patches consist of 41 plant species belonging to 26 families. The biomass per unit area on the open plain is much less than that of the shrub patches. Metal accumulation in the shoots was found in both vegetation types. The most dominant family in this ecosystem was Fabaceae followed by Capparaceae, Salicaceae, Rutaceae and Rubiaceae. The families Salicaceae, Menispermaceae, Rhizophoraceae and Violaceae were recorded only from the serpentine ecosystem and not in the adjacent non-serpentine vegetation. Of these species *Vernonia zeylanica* (Asteraceae) is endemic to Sri Lanka and *Cassia kleinii* (Fabaceae) is found only in Sri Lanka and Southwest India. All the species are tolerant to high metal content in the soil, either by accumulation or exclusion. Some of the prostrate species are hyper-accumulators of nickel. Conservation measures that integrate the local human population are imperative to preserve this site. The National Man and Biosphere committee of UNESCO has identified this site as a possible geo-park.

017. ECOLOGICAL STUDIES ON THE ENDEMIC *CERASTIUM UTRIENSE* (CARYOPHYLLACEAE)

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Cerastium utriense Barberis (Caryophyllaceae) is an endemic plant from the Voltri Group, an ophiolitic outcrop from northwestern Italy. Despite the ecological significance of this species little is known about its ecological requirements and environmental range, thus the main objective of our work is to analyze and clarify these aspects. On the basis of a preliminary survey on the distribution area of the species, 30 plots were selected and studies on flora, vegetation and soil were carried out. Biological and chorological spectra were calculated and the floristic composition was defined (based on Grime's functional plant groups and Landolt's indicator values). Based on floristic diversity and several environmental parameters of the study areas, such as the physicochemical and biological properties of the soils (texture, pH, trace elements composition, cation exchange capacity, etc.), 10 plots were selected and more closely investigated. In particular, we outlined the strategies adopted by the species frequently living on serpentine soils (accumulating metallophytes, non-accumulating metallophytes, ubiquist species, etc.) and their relationships and interactions with soil and parent rock. Our studies characterized *C. utriense,* frequently associated with *Euphorbia spinosa* L. subsp. *ligustica* (Fiori) Pignatti, *Bromus erectus* Huds. and *Minuartia laricifolia* (L.) Schinz et Thell. subsp. *ophiolitica* Pignatti, as an exclusive serpentinophyte able to metals from its tissues, mainly growing on scree and rock fissures, and only very rarely growing on well developed soils.

018. ANALYSIS OF PHYSICOCHEMICAL PROPERTIES, SOIL BIOTA AND HEAVY METALS IN THE SERPENTINITE MINING AREA OF SOUTHERN RAJASTHAN (INDIA)

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Serpentinite belongs to the ultramafic clan of rocks in which minerals of iron and magnesium silicates predominate. Serpentinite rock is easy to recognize, with its gray to green color and smooth to soapy feel. Serpentinites are often laced with heavy metals such as chromium and nickel. Weathering processes induced by local climates break down or alter parent rock to yield soil: in the case of serpentinites a clay mineral often forms that is not found in the rock. The present investigation showed that serpentinite soils in S. Rajasthan are rich in nickel, chromium, cobalt, zinc and boron. These soils are toxic due to heavy metals, low levels of potassium and phosphorus, and low calcium/magnesium ratios, and so inhibit growth of many plants. The flora is generally very distinctive with specialized, slow growing species. This clearly indicates that heavy metals are potentially cytogenic and mutagenic for plants growing in the serpentinite mining area. The pH of soil is typically 6.8 and above, which makes primary plant nutrients unavailable. The excellent drainage of the soil, due to the relative absence of organic matter, facilitates the leaching of nutrients. The dominant plant species found on serpentine soils of S. Rajastan will be reported.

019. FLORA OF THE NEW IDRIA SERPENTINE MASS (CALIFORNIA, USA)

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The 125 square kilometer New Idria serpentine mass contains the highest peak in the Diablo Range and is one of the most unique serpentine landscapes in California, USA. Its vegetation varies from high-elevation conifer forests dominated by *Pinus sabiniana* (Pinaceae), *Pinus coulteri*, *Pinus Jeffreyi*, and *Calocedrus decurrens* (Cupressaceae), to chaparral dominated by *Arctostaphylos glauca* (Ericaceae), *Ceanothus cuneatus* (Rhamnaceae), and *Quercus durata* (Fagaceae), to moonscape barrens completely devoid of any vegetation. Hidden within the understory of the forest and chaparral grow the rare jewels of the New Idria serpentine mass including *Camissonia benitensis* (Onagraceae), *Fritillaria falcata* (Liliaceae), *Layia discoidea* (Asteraceae*), Solidago guiradonis* (Asteraceae), and *Monardella antonina* subsp. *benitensis* (Lamiaceae), among others.

020. THE NICKEL HYPERACCUMULATING PLANTS OF THE SERPENTINES OF TURKEY AND ADJACENT AREAS

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Exploration of the plants of serpentine soils in western and central Turkey and neighboring countries has shown that the region includes more than 50 species capable of hyperaccumulating nickel (to >0.1% of the plant dry weight). The hyperaccumulators in this region belong to the Brassicaceae (*Aethionema, Alyssum, Bornmuellera, Cochlearia, Pseudosempervivum* and *Thlaspi*) and the Asteraceae (*Centaurea*). We summarize here the present state of knowledge of the hyperaccumulators, which include the recently discovered *B. kiyakii*. Some of these species appear to be serpentine-endemic and invariably Ni hyperaccumulating, while others show a more complex pattern of distribution and Ni-accumulating behavior. Many of these species are good subjects for biochemical studies on the nature of the Ni-accumulation and sequestering processes; in some cases further taxonomic work is required, by traditional and DNA methods. There is also interest in exploiting the Ni hyperaccumulation both for remediation of Ni-contaminated soils ("phytoremediation") and for economic selective extraction of the Ni by cropping hyperaccumulators ("phytomining"). Although there is potential for these processes to be used in Turkey, there is a need for further exploration of the natural resource, and attention must be paid to conservation issues as some of the species are quite rare.

021. GEOECOLOGY OF SERPENTINE IN EASTERN NORTH AMERICA: CRITICAL INFORMATION GAPS AND FUTURE DIRECTIONS

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While much attention has been paid to serpentine outcrops worldwide, the literature on eastern North America is scant. We present information on what is currently known and discuss areas in need of future study. To date, 750 taxa of vascular plants belonging to 92 families have been reported from serpentine in the region. Two taxa, *Agalinis acuta* and *Schwalbea americana*, are federally endangered in the United States. Globally, six species (*Adiantum viridimontanum*, *Minuartia marcescens*, *Pycnanthemum torrei*, *S. americana, Scirpus longii* and *Symphyotrichum depauperatum*) found on regional outcrops are listed as imperiled (G2) while one species (*A. acuta*) is listed as critically imperiled (G1). *Cerastium arvense* var. *villosum* is the only recognized serpentine endemic plant for eastern North America while *A. viridimontanum*,

Aspidotis densa, *M. marcescens*, and *S. depauperatum* are largely restricted to the substrate. Based on current reports, *A. viridimontanum*, *A. densa*, and *M. marcescens* should be considered endemic to serpentine in eastern North America. Studies list 163 species of lichens and 147 species of bryophytes for the region. None of the species found are restricted to the substrate. Compared to other regions, ecophysiological and evolutionary investigations are scant. Biosystematic investigations are restricted to the taxa *Adiantum aleuticum*, *C. velutinum* var. *villosissimum* and *S. depauperatum*. Studies on the capacity to hyperaccumulate metals and the ecological consequences of metal accumulation are also under-explored. One report from eastern Canada lists *Arenaria humifusa*, *M. marcescens*, *Packera paupercula* and *Solidago hispida* as hyperaccumulating Ni although the initial findings have yet to be confirmed by subsequent investigations.

022. SERPENTINE AND NONSERPENTINE ECOTYPES OF *COLLINSIA SPARSIFLORA* ASSOCIATE WITH DISTINCT ARBUSCULAR MYCORRHIZAL FUNGI ASSEMBLAGES

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Although plant adaptation to serpentine soils has been studied for several decades, the mechanisms of plant adaptation to edaphic extremes are still poorly understood. Arbuscular mycorrhizal fungi (AMF) are common root symbionts that can increase plant host establishment and growth in stressful environments. However, little is known about the role plant-AMF interactions play in plant adaptation to serpentine. As a first step toward understanding this role, we examined AMF assemblages associated with field populations of serpentine and nonserpentine ecotypes of the California native plant *Collinsia sparsiflora*. We sampled roots of *C. sparsiflora* from three serpentine and three nonserpentine sites in close proximity (110 m to 1.94 km between sites) and analyzed the small subunit rDNA gene amplified from root DNA extracts using AMF-specific primers. A total of 1,952 clones from 24 root samples (four from each site) were sequenced. We found 19 OTUs representing taxa from 6 AMF genera, including one serpentine-specific OTU. We used Bray-Curtis similarity, hierarchical clustering, multidimensional scaling (MDS) and analysis of similarity (ANOSIM) to compare root sample AMF assemblages. These analyses clearly showed that plant ecotypes associated with distinct AMF assemblages; an *Acaulospora* OTU dominated serpentine assemblages and a *Glomus* OTU dominated nonserpentine assemblages. Species diversity and evenness were significantly higher in serpentine assemblages. Finally, RELATE analysis showed a relationship between ecotype AMF assemblages and soil nutrients. This study reveals a strong relationship between AMF associates and plant adaptation to edaphic extremes**.**

023. SOIL AND VEGETATION HETEROGENEITY ON A SERPENTINE SITE IN USSANGODA, SRI LANKA

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Weathered ultramafic rocks form a serpentinite-bearing lateritic cap on a flat plain at Ussangoda on the southern coast of Sri Lanka. Two distinct forms of vegetation grow on this soil: the plain is dominated by prostrate species producing very low biomass per unit area and small isolated patches of thorny shrubs of higher biomass (occupying less than 5% of the total area). This area receives <1250 mm annual rainfall, with daytime temperatures of 36 ºC and 40% relative humidity. Soil samples were collected (0-10cm) by stratified random sampling from the plain and shrub communities, and their physical and chemical parameters were determined. Soil textures under the two communities were similar, with 90–95% sand and 5–10% silt and clay. The mean magnesium content was similar on the plains (315 $\mu g\ g^{-1}$) and under the shrubs (329 $\mu g\ g^{-1}$). The mean calcium content was significantly higher under the shrubs (593 $\mu g\ g^{-1}$) than on the plains (208 $\mu g\ g^{-1}$), giving Ca:Mg ratios of 1.8 and 0.6, respectively. Organic nitrogen was significantly higher under the shrubs (1874 $\mu g\ g^{-1}$) than on the plains (708 $\mu g\ g^{-1}$). Soil moisture content and organic matter were also higher under the shrubs. Chemical heterogeneity of ultramafic rocks during their formation may perhaps have contributed to the differences observed in the soil chemistry, which is reflected in the distinct forms of vegetation, species composition and biomass production of the surface flora.

024. LICHEN FLORA OF SERPENTINE IN THE MIDDLE URALS OF RUSSIA

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Lithophilous lichen biodiversity was studied on rocky outcrops from the Middle Urals. Ultramafic rocks (serpentine, pyroxenite) as well as limestone, granite and basalt were sampled. Serpentine and limestone were the substrates richest in species: both had 84 lichen species. Despite the equal number of species, the species compositions of each substrate differed. Only 11 species were amphitolerant (growing on all rock types) while the others were more or less selective. The serpentine lichen flora was rather similar to that of pyroxenite and basalt, with *Aspicilia cinerea*, *Bellemerea cupreoatra*, *Rhizocarpon grande*, *Scoliciosporum umbrinum* and others growing on all of these substrata. The serpentine lichen flora had rather low specificity, as

only 14 species (such as *Acarospora oligospora*, *Fuscopannaria leucophaea*, *F. praetermissa*, *Peltula euploca*, *Ramalina pollinaria*, and *Toninia cinereovirens*) were not found on other rocky substrata (limestone and granite had 49 and 22 obligate species, respectively). Some "strictly" calciphilous lichens such as *Aspicilia contorta* subsp. *contorta*, *Endocarpon pusillum*, *Lecania turicensis*, *Phaeophyscia constipata* were found on serpentine. Some predominantly granitophilous species (*Stereocaulon tomentosum*, *Porpidia cinereoatra*, *Rhizocarpon grande*) also grew on serpentine. This mixture of species brings about the intermediate character of the serpentine lichen flora. Study of heavy metal accumulation in lichen thalli revealed no correlation between metal levels in lichens and their rock substrate. This implies that pH (rather than availability of metal ions) is a main factor determining lichen species affinity to rocks.

025. PLANT DIVERSITY AND VEGETATION OF ULTRAMAFIC ROCKS IN THE MIDDLE URALS OF RUSSIA

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Ultramafic rocks are distributed mainly on the eastern slope of the Middle Urals. They are covered primarily by southern-taiga forests and only on riverbanks are represented as rocky outcrops with petrophytic vegetation. Ultramafic outcrops on riverbanks are composed of dunite, serpentine, pyroxenite, apoharzburgite and harzburgite. Floristic composition and vegetation of southern slopes differ from the zonal taiga forests and contain xerophytic vegetation typical of rocky steppe. The vegetation is formed by rocky-steppe and steppe species (55% of total species list) that are not found in the zonal flora. Most species are rare in the Middle Urals and grow at the northernmost portion of their distributions. Six percent of species growing on ultramafic outcrops are endemic. Ultramafic rocks have a richer flora compared with acidic rocks whereas floras of ultramafics and limestone are equal in species richness. Many species grow on both rock types. Some species (*Lychnis sibirica, Asplenium viride*) grow only on serpentine. Different types of ultramafic rocks differ in their floristic composition. Serpentines and pyroxenites are richer in species compared with dunite and harzburgite and have a similarity coefficient as high as 72%. Floristic composition of rock outcrops on different rivers varies and correlates with rock type, variability of ecotopes, and river history (which has affected species migration patterns). Rock type and exposure have the greatest effects on species composition, which in turn affects the ecological, biomorphological and coenotical spectra of vegetation.

026. ECOLOGY OF THE SERPENTINES OF TIEN SHAN

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Many years of research in Tien Shan have allowed the study of two types of serpentines originated on ultrabasites and dolomites and the discovery of a new variety developed on conglomerates (Dolzhenko 1975). These serpentines have different geological, mineralogical, geochemical and ecological particularities. Serpentines formed on the ultrabrasite are distributed in the ophiolite belts of North Tien Shan. They often contain asbestos, talc and chrysolite mixed with carbonate and chert and have higher concentrations of Ni, Co, Cu and Pt. The rocks are strongly weathered. On their surface soil and plants are usually absent, but marmot burrows are present. Serpentines on dolomites are widely distributed in South Tien Shan along deep faults and they contain talc, asbestos, crushed host rocks and inclusions of Pb and Hg minerals. Such serpentines in arid climates do not form soils and lack plants but are inhabited by rodents. They are not favorable for agriculture and human habitation. A new type of serpentines is discovered in Middle Tien Shan at the contact zone of granites intruded into limestones and dolomite separated from conglomerates by faults. They are localized only in the last type of rocks as a result of solutions that extracted Mg from dolomites and Au from conglomerates. Because of this, in the central part of the alteration zone are quartz veins with Au (2 g t^{-1}). These new type serpentines are distinguished from the others by good soil cover and favorable ecological conditions.

027. SPECIAL ULTRAMAFIC VEGETATION OF THE GLACIATED APPALACHIAN QUÉBEC REENTRANT (EASTERN TOWNSHIPS, CANADA)

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Using data from herbaria and conservation field surveys, the vascular flora of scattered low-elevation ultramafic outcrops is described for southern Québec. Between the Appalachians of northern Vermont and the Chaudière River, an intermittent belt totaling 200 km^2 of these outcrops follows the northeast-running Quebec Reentrant emplaced intact during the Ordovician period (488-444 million years ago). Ultramafic substrates have only been continuously available to life since glacial retreat 12,000 years ago. Only one endemic plant species has yet been described (1991), restricted globally but paradoxically a recurring serpentine indicator at most local sites, and the one most finely tuned to serpentine soils. Based on current distributions, the hypothesis is that serpentine-exclusive/preferential species migrated to Québec along a receding glacial front from southern refuges or from western cordillera. Consideration is given to the

variable species assemblages recorded throughout the archipelago of Québec ultramafics, with special attention paid to serpentine-exclusive/preferential species, including those present in other climates or biomes and partial to either limestone or acidic soils in those places. In Québec one observes the latitudinal displacement effect of serpentine, where northern species indifferent to ultramafic substrates penetrate southward along serpentine, and analagous southern ones penetrate northward. The dozen rarest species, of conservation concern nationally, occupy only a tiny percentage of available sites, often scarcely overlapping. Open-pit asbestos mining has reduced habitat significantly, but some abandoned quarries in Thetford Mines afford opportunities to carry out studies on dispersal, recolonisation and succession.

POSTER PRESENTATIONS

028. IMPORTANCE OF ARBUSCULAR MYCORRHIZAS WITHIN PIONEER CYPERACEAE ENDEMIC FROM NEW CALEDONIA ULTRAMAFIC SOILS

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Cyperaceae was originally recognized as a non-mycorrhizal plant family. Recent studies demonstrated the ability of some Cyperaceae species to form arbuscular mycorrhizas. Ecological adaptive traits were evoked to explain the mycorrhizal status: non-mycorrhizal or arbuscular mycorrhizal. Nevertheless, the potential role of this symbiosis in Cyperaceae growth, survival and physiology remains poorly documented. New Caledonia serpentine plant communities are composed of 80% endemic species, most of them forming mycorrhizas, which develop on ultramafic soils rich in iron and heavy metal (Ni, Cr, Mn, Co), poor in N, P and K and unbalanced in Ca/Mg ratio. The mycorrhizal status of 8 pioneer Cyperaceae species representing five genera from the ligno-herbaceous endemic vegetation (locally called the "maquis minier") has been investigated under field conditions. All species showed mycorrhization. Mycorrhizal frequencies ranged from 8 to 57% and mycorrhizal infection intensities ranged from 2 to 12%. A glasshouse experiment assessed the potential role of arbuscular mycorrhizas in plant survival and development. The Cyperaceae species *Costularia comosa* was inoculated with arbuscular mycorrhizal fungi from New Caledonian maquis minier. In spite of weak colonization, the experiment clearly demonstrated the role of arbuscular mycorrhizas in plant growth and survival improvement. The results suggest that plant environment is a major trait to consider when examining plant mycorrhizal status.

029. A FLORISTIC SURVEY OF BRYOPHYTES ON A PERIDOTITE AND A GRANITIC OUTCROP IN DEER ISLE, MAINE, USA

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We describe the bryophyte flora of a peridotite and a granitic outcrop from Deer Isle, Hancock County, Maine, USA, and examine tissue elemental concentrations for select species collected from both sites. Fifty-five species were found: 43 on serpentine and 26 on granite. Fourteen species were shared in common. Twelve species are reported for the first time from serpentine soils. Soil analyses showed significant differences in soil chemical features, including Ca:Mg ratio, Ni and Cr, between the two sites. None of the species tested accumulated excessive amounts of heavy metals although the serpentine mosses tested had consistently higher Ni and Cr concentrations and Ca:Mg ratios <1 compared to those collected from granite. The finding of a greater number of species on the peridotite outcrop, including several known to be tolerant of heavy metals elsewhere, suggests that there is a unique serpentine-substrate effect for bryophytes in eastern North America, warranting further studies on key species.

030. *SAXIFRAGA GEMMULOSA* (SAXIFRAGACEAE), A NICKEL BIOINDICATOR SPECIES ENDEMIC IN ULTRAMAFIC AREAS OF THE SOUTHERN IBERIAN PENINSULA

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The western Cordillera Bética mountains contain the largest area of ultramafic rocks in the Iberian Peninsula. The main flora of this southern territory was screened for Ni accumulation. We found *Alyssum serpyllifolium* subsp. *malacitanum* Rivas Goday (Brassicaceae) as a Ni hyperaccumulator and *Saxifraga gemmulosa* Boiss. (Saxifragaceae) as a Ni bioindicator.

Saxifraga gemmulosa is a rare species endemic to ultramafic outcrops of the Sierra Bermeja (Estepona, Málaga) developing mainly in crevices of basic or ultrabasic rocks where it can be found with other serpentinophytes such as *Asplenium adiantum-nigrum* subsp. *corunnense* (Christ) Rivas Mart. (Aspleniaceae). Variation in Ni content and other representative elements in *S. gemmulosa* and its soils in the territory of Sierra Bermeja are studied by Inductively-Coupled Plasma-Mass Spectrometry (ICP-MS).

031. THE MYCORRHIZAL STATUS OF ULTRAMAFIC PLANTS OF CENTRAL IRAN

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Ultramafic soils contain high concentrations of Mg and Fe, and also relatively high amounts of Ni, Cr and Co. Concentrations of N, P and K in these soils are usually low and the Mg/Ca ratio is high. They tend to be shallow and dry. Such conditions are unfavorable for the growth of many plant species; however, some are able to grow on even the most extreme substrata. Arbuscular mycorrhizas (AM) can be important in plant P nutrition. Colonization of plant roots by AM fungi can also reduce the toxic effects of heavy metals on plants. In this study, the occurrence and infection rate of AM in 81 plant species growing in ultramafic soils of Anarak, Central Iran, were surveyed. Plant species investigated belonged to 24 families, mostly Asteraceae (16), Poaceae (14), Brassicaceae (11), Lamiaceae (6) and Boraginaceae (5). The growth forms were perennial herbaceous (45), annual herbaceous (35) and one a small tree. Among these plants, 62 species were AM, while the other species were not colonized by any mycorrhiza. Extent of colonization in 40 species was quite high (more than 50%). The intensity of colonization was very high in 54 species and low in 8 species. All 11 species belonging to the Brassicaceae were colonized or contained a low colonization extent and intensity. None of the plant species growing in Anarak were Ni hyperaccumulators. We conclude that AM infection is a suitable strategy for tolerance of these plant species in this dry ultramafic area.

032. VEGETATION COMPOSITION, DIVERSITY AND BIOMASS ALONG ENVIRONMENTAL GRADIENTS IN SUSÚA STATE FOREST, PUERTO RICO

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The southwest geologic province of Puerto Rico contains three linear belts of ultramafic rocks.

Susúa Forest is located on the southern-most tip of the main belt and is composed of two ridges separated by the Rio Loco river valley. A study was conducted to document the composition, diversity and biomass of Susúa vegetation along rainfall and soil depth gradients. In 2002, we established 50 plots (100 m^2 each) in Susúa over a range of soil depths, recording the species and diameter at breast height (DBH) of woody vegetation in the plot. In 2003, we weighed a subset of trees to develop an allometric equation for total aboveground biomass based on DBH. With the field data, we calculated abundance values, relative importance values (RIV), and species diversity indices. Susúa is composed primarily of native vegetation based on RIV; however, *Swietenia mahagoni* has become well established in the forest since its introduction in the 1930s, accounting for 19% of the aboveground biomass in Susúa. Plots on the ridges and slopes overlap in their species composition and tend to have numerous, small diameter stems (mean=18 kg $stem^{-1}$). In contrast, alluvial plots have a distinct species composition and have fewer overall stems with larger individuals (mean=25 kg $stem^{-1}$). Plots in the north of Susúa have greater species diversity than the south, which may be attributed to seed dispersal from the north-west. Plots in the north also have greater aboveground biomass, which correlates with greater precipitation in the north due to orographic rain patterns.

033. CHARACTERIZATION OF ARBUSCULAR MYCORRHIZAL FUNGI FROM *PSYCHOTRIA* ROOTS IN SERPENTINE SOILS OF NEW CALEDONIA

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A considerable portion of New Caledonia (about 40% of the main island) has been progressively covered with a sheet of serpentine rocks. These rocks, through erosion and alteration, have given birth to soils exceptionally enriched in heavy metals (mainly Ni, Co, Mn and Cr), and especially poor in organic matter and nutritive elements. These serpentine soils are challenging habitats for plants and favor vegetation adapted to their nutritional poverty, mineral disequilibrium and elemental toxicity. The ability to tolerate excessively high levels of Ni and other heavy metals by the endemic Caledonian flora may be an evolutionary response to life on a serpentine substrate. In order to better understand the adaptations of plants to survive on these highly toxic soils, we focused our attention on two *Psychotria* species: *Psychotria douarrei* and *P. baillonii*. These two species co-exist on the serpentine soils of the forest of Mont Koghi in New Caledonia. In order to highlight the mycorrhizal impact upon Ni tolerance of these species, we compared the quality and importance of mycorrhization in relation with the content of Ni, P and N in the leaves. Furthermore, we show here the characterization of fungi associated in the rhizosphere of the two species by means of their rDNA sequences.

034. *ADIANTUM VIRIDIMONTANUM, ASPIDOTIS DENSA* AND *MINUARTIA MARCESCENS:* ADDITIONAL SERPENTINE ENDEMICS FROM EASTERN NORTH AMERICA?

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Serpentine regions around the world are known to harbor disproportionately high rates of plant endemism with rates decreasing with distance from the equator. Remarkable cases of serpentine endemism occur in New Caledonia and Cuba, with 3178 and 920 endemic taxa, respectively, found solely on serpentine. California alone, in western North America, is home to 176 taxa endemic to serpentine. Despite the patchy occurrence of serpentine in eastern North America from Quebec and Newfoundland south along the Appalachian orogen to Alabama, only one taxon, *Cerastium velutinum* var. *villosissimum*, has been broadly recognized as a serpentine endemic for the region. Based on reports in the literature and voucher specimens, we suggest that *Adiantum viridimontanum* and *Minuartia marcescens* be considered endemic to serpentine soils from the east coast of North America. *Aspidotis densa*, a strong serpentine indicator in western North America, is known solely from serpentine soils in eastern North America and should be considered endemic to the substrate there.

035. ECOLOGY OF SAXICOLOUS CYANOBIONT LICHENS ON SERPENTINE FROM THE MIDDLE URALS, RUSSIA

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Fourteen species of cyanobiontic lichens were found on serpentine outcrops from the Middle Urals of Russia: *Collema cristatum, C. flaccidum, C. polycarpon, C. tenax, Fuscopannaria leucophaea, F. praetermissa, Leptogium tenuissimum, Lichinella stipatula, Peltigera didactyla, P. lepidophora, P. ponojensis, P. rufescens, Peltula euploca* and *Stereocaulon tomentosum*. Four genera of photobionts are the algal partners in these lichens. The main is *Nostoc*, which is a primary or secondary algal partner in *Collema*, *Fuscopannaria*, *Leptogium* and *Stereocaulon*. *Lichinella stipatula* has *Pleurocapsa* and *Peltula euploca* has *Chroococcu*s as photobionts. Descriptions of lichen cover were made using 1 x 1 cm mesh grid to evaluate cover of *Collema, Lichinella* and *Peltula* growing directly on rock. Azimuth and rock inclination were also recorded on sample plots. The maximum cover of *Collema* species was found on slopes facing north, northeast or northwest. *Collema* species preferred almost vertical rocks, also growing rarely in overhangs. These habitats are wet and cool and often covered by forest that gives

additional shade and air humidity. *Lichinella* and *Peltula* were found mainly on south slopes. These slopes are usually open and heat up to 50 °C on a summer day. *Lichinella* and *Peltula* also prefer vertical rocks that give them an ability to use seepage water and to stay wet longer than other lichens. Lichen species with *Nostoc* are likely to prefer shade and wet habitats while *Pleurocapsa* and *Chroococcus* are able to withstand periods of drought.

036. DISTRIBUTION AND DIFFERENTIATION OF THE SERPENTINE PLANTS IN HOKKAIDO AND THEIR CHEMICAL CHARACTERISTICS

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The ultramafic rock area in Hokkaido spreads from 42 to 45°N, 142 to 143°E and 100 to 1900 m above sea level. The ultramafic plants in Hokkaido comprise 46 taxa, which comprise 70.8% of the ultramafic plants in Japan. Forty-four taxa were endemic to Hokkaido. Above all, 12 taxa in Mt. Apoi and 9 taxa in Mt. Yupari were endemic to their respective mountain. The P content in the ultramafic plants was lower, while the contents of K, Ca and N were higher than those in the common plants and trees. The ultramafic plants also actively absorbed other essential elements. The Ni content of the serpentine plants increased proportionally to that of the exchangeable Ni content in the soil up to 10 mg kg^{-1} soil but did not increase further, in contrast to the Ni content of the common plants that increased linearly in proportion to the content of exchangeable Ni in the soil. Among the plants investigated, a common plant, *Thlaspi japonicum*, was recognized for its extraordinary Ni accumulation (1,299 mg kg^{-1} on average), indicating that this is the only Ni-hyperaccumulator in Japan at present. Eight taxa (7 ultramafic plants: *Viola yubarina*, *Ranunculus acris* var. *nipponicus* form *yuparensis*, *Lagotis takedana*, *Draba japonica*, *Viola sacchalinensis* var. *alpina*, *Saussurea chinophylla* and *Primula yuparensis*, and 1 common plant: *Allium schoenoprasum*) were also recognized as strong Ni-accumulators.

037. FOLIAR MN ACCUMULATION IN EASTERN AUSTRALIAN HERBARIUM SPECIMENS: PROSPECTING FOR 'NEW' MN HYPERACCUMULATORS AND ITS POTENTIAL APPLICATION IN TAXONOMY

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Currently only ten Mn hyperaccumulators have been reported worldwide, and among them there exist a variety of leaf-Mn sequestration patterns thus far not evident in other hyperaccumulating plants. The majority of these mostly woody species are native to the serpentine soils of New Caledonia. Three belong in the Proteaceae, including two that were formerly in the genus *Macadamia*. By virtue of their geographic distributions and family affiliations, the New Caledonian Mn hyperaccumulators are linked to the flora of the east coast of Australia, where the only known Australian Mn hyperaccumulator, *Gossia bidwillii* (Myrtaceae), occurs and also where the majority of the world's *Macadamia* species are found. The natural habitats of *Gossia* and *Macadamia* include high Mn-available lateritic and ultramafic soils. Although the taxonomy of *Gossia* and related genera was recently revised, there are some populations in *Gossia* that are not easily resolved. The use of foliar Mn concentrations as a taxonomic tool has been previously suggested. Species from the following groups of eastern Australian genera were sampled from the Queensland Herbarium collection: (a) *Austromyrtus, Lenwebbia* and *Gossia* (Myrtaceae), (b) *Macadamia* (Proteaceae), and (c) *Maytenus* and *Denhamia* (Celastraceae). Group (c) Celastraceae are considered similar to the *Maytenus* of New Caledonia, which currently includes two Mn-hyperaccumulating subspecies of *M. fournieri.* Total foliar Mn concentrations in herbarium leaf fragments were obtained by ICP-OES analyses. The preliminary data indicate up to six 'new' Mn hyperaccumulators that are mostly tropical rainforest species, and demonstrate considerable variability of the hyperaccumulator trait within *Gossia*.

038. THE ROLE OF THE SERPENTINE SUBSTRATE ON THE MORPHOLOGICAL VARIATION AND CHEMICAL COMPOSITION IN *TEUCRIUM CHAMAEDRYS* (LAMIACEAE)

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Teucrium chamaedrys is the most variable taxon of the genus *Teucrium,* which is widely distributed in Europe as well as in Bulgaria. The species shows a high degree of

morphological and karyological diversity. It fits Kruckeberg's concept of a "bodenvag" species. The aim of this study was to investigate serpentine and non-serpentine populations and to evaluate whether differences in morphological variation are a result of the serpentine effect. In addition, the chemistry of the populations was studied. Nine populations distributed on and off serpentines were investigated and 23 morphological features were studied by univariate and multivariate statistical analyses. The results demonstrated the delimitation of the serpentine from the non-serpentine populations. Using these ecotypes as classification factors in the discriminant analysis it can be stated that stem height, stem length up to the first leaf pair and internode length between the second and the third leaf pairs, were features with greatest discriminant ability. Variation ranges for most characters of both ecotypes overlapped considerably. Variation was higher for the vegetative features while for the reproductive ones the differences were less clearly expressed. The serpentine soil samples showed abnormal content of Ni, Cr, Cd, Co and Pb. The Ca/Mg ratio was below 1 in four of the serpentine samples. The accumulation of Ni, Cr, Co and Pb in aboveground plant parts for all serpentine populations was higher than non-serpentine populations. The species *Teucrium chamaedrys* is tolerant of serpentine soils and demonstrates a specific ecotype reaction to them.

039. CHARACTERIZATION OF THE LIGNEOUS VEGETATION OF THE ULTRAMAFIC MASSIF OF BENI BOUSERA (COAST OF GHOMARA, NORTHERN MOROCCO)

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The massif of Beni Bousera corresponds to an important ultramafic outcrop (Péridotite) on the Mediterranean coast of Rif. We examined the distribution and abundance of species within two types of soil: serpentine soil on ultramafic substratum and the adjacent non-ultramafic soil to compare the communities using a quantitative ecological approach. We also evaluated the biodiversity of the shrub stratum of the serpentine massif of Beni Bousera through the measurement of species richness and richness of endemic taxa. Detrended correspondence analysis (DCA) underlined a floristic gradient that corresponded to an ecological gradient associated with altitude and the nature of substratum. For each sample, we evaluated the diversity indices of the shrub stratum which generally showed a high diversity (species richness and endemism) on ultramafic soil. Analysis of hierarchical classification (Cluster) identified the principal plant communities. Generally, we estimated that the singularity of the ultramafic substratum allows a significant differentiation of the vegetation. The results showed that the serpentine area of Beni Bousera has high ecological value that should be conserved. However, it is subject to a high degree of degradation which threatens its ecological equilibrium.

040. VASCULAR PLANTS OF ADJACENT SERPENTINE AND GRANITIC OUTCROPS OF DEER ISLE, ME, USA

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We surveyed the vascular vegetation of abandoned serpentine and granite quarries of similar aspects and landuse histories, located on Deer Isle, Maine. Using a grid of circular plots, we tested the elemental concentrations of topsoil and associated foliar tissue for geochemical and physiological evidence of the "serpentine syndrome." No regionally rare vascular taxa were recorded inhabiting the serpentine quarry. The species composition differed between the two quarries: certain species abundant on the granitic quarry were absent on serpentine and *vice versa*. The exposed serpentine quarry had greater mean species richness and Shannon-index values than the granite quarry, despite a smaller total area. This pattern was reversed in the forested areas surrounding the outcrops, and may be due to greater soil development on the exposed serpentine substrate. Soil samples from the serpentine quarry showed relatively high levels of Ni (mean 38.78 compared to 0.89 mg kg^{-1} on granite) and Mg (1740.52 compared to 24.72 on granite), and a low Ca:Mg ratio (less than 1 compared to ~4 on granite). Foliar samples from selected plant taxa mirrored this pattern (mean Ni levels 17.95 versus 4.67 ppm, mean Ca:Mg 0.89 versus 3.52), although certain metals such as Zn and Mn appeared in higher levels in granitic samples. The floras of the Deer Isle quarries differ most distinctly in terms of tissue elemental concentrations and lack the dramatic phytogeological delineations seen in the ultramafic grasslands of California. However, the "serpentine effect" is certainly present in the Deer Isle outcrop, and future studies in Maine are necessary for an accurate characterization of its serpentine flora.

SESSION: *ECOLOGY & EVOLUTION*
MODERATOR: SUSAN P. HARRISON

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ORAL PRESENTATIONS

041. A PREDICTABLE EVOLUTIONARY PATHWAY TO SERPENTINE ENDEMISM AND ITS CONSEQUENCES IN THE CALIFORNIA FLORA

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Macroevolutionary trends indicate that repeated and predictable historical processes drive biological diversification. Here, we examine the predictability of historical processes leading to the origin and persistence of serpentine endemic plant taxa in the flora of California, USA. There are 246 serpentine endemic taxa in the state, representing 93 genera and 39 families, as well as 352 taxa that both occur on and off serpentine soils (*i.e.* serpentine tolerators). Taxonomically, we found serpentine endemics are significantly more likely to arise in genera containing tolerator species, but many tolerator-containing genera contain no endemic taxa. This initial finding suggested a directional evolutionary pathway from non-tolerator to tolerator to endemic taxa. We tested this model using molecular phylogenies for over 20 genera containing serpentine endemics for which adequate DNA sequence data was available using Genbank database mining techniques. We found several instances of significant directionality, generally supporting the evolutionary pathway from non-tolerators to tolerators to endemics. Surprisingly, the transition to serpentine endemism generally did not correlate with increased diversification rates, likely reflecting the relatively young age of most serpentine lineages based on an approximate molecular clock. Few endemic lineages were found to be older than 10 million years, refuting widespread existence of 'paleoendemics'. Testing these macroevolutionary trends in other serpentine floras will provide valuable comparative insights into the evolutionary forces driving patterns underlying serpentine biodiversity.

042. OAKS ON AND OFF SERPENTINE: ECOTYPIC VARIATION AND THE ROLE OF MYCORRHIZAL FUNGI FOR PLANT GROWTH

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Quercus ilex subsp. *ballota* is a widespread mediterranean obligatory mycorrhizal species and the only tree able to grow on the serpentine sites of northeastern Portugal. I used a reciprocal transplant experiment to investigate the existence of oak serpentine local adaptation as well as the role of mycorrhizal fungi on this plant's growth. I collected and germinated acorns from serpentine and non-serpentine sites and grew the seedlings on serpentine and non-serpentine soil, with and without mycorrhizal fungi, in a greenhouse environment for 8 months. I found significant differences on plant growth associated with soil type, acorn origin and presence of mycorrhizal fungi. Serpentine plants grew less than plants of non-serpentine origin, all plants tended to grow more on non-serpentine soil and mycorrhizal fungi increased plant growth on non-serpentine soil. Serpentine plants did not show better performance on their native soil. These results suggest physiological differences between serpentine and non-serpentine seedlings but do not support the existence of serpentine local adaptation. Further research including extended growth periods is needed to clarify the presence of ecotypic variation associated with serpentine soils in *Q. ilex* subsp. *ballota*.

043. NICKEL HYPERACCUMULATORS MOBILIZE NICKEL INTO NEW CALEDONIAN EPIPHYTES

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Hyperaccumulator plants mobilize large amounts of certain elements from the soil into their tissues, where they then may be transferred to other organisms in those communities. Using a humid tropical forest site in New Caledonia, we tested whether epiphytes (mosses and liverworts) growing on Ni hyperaccumulators contained greater levels of Ni than those growing on non-hyperaccumulators. We selected two Ni hyperaccumulator species, *Psychotria douarrei* and *Hybanthus austrocaledonicus*, pairing individuals of each species with similar-sized non-hyperaccumulators and collecting epiphytes from each for elemental analysis. In both cases, epiphytes collected from hyperaccumulating hosts had significantly increased Ni concentrations.

Epiphyte Ni concentrations often exceeded the threshold used to define Ni hyperaccumulation (1000 μg g^{-1}), showing that some epiphytes growing on hyperaccumulators also hyperaccumulate Ni. We conclude that Ni moves between host hyperaccumulators and epiphytes, thus mobilizing Ni still further into the food webs of these humid tropical forests.

044. TESTING SOIL NUTRIENTS AND PLANT GENOTYPIC IN SERPENTINE PLANT – SOIL INTERACTIONS

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Plant/soil microbial community feedback can have important consequences for species composition of both the plant and soil communities. What is not known, however, is to what effect nutrient availability or plant genotype may influence feedback dynamics. In this research, I tested whether plant/soil community feedback occurs and if increased soil fertility altered the plant/soil community interactions. In two glasshouse experiments, plant and AM fungal performance was assessed relative to the soil community, collected from under these co-occurring plants in serpentine grasslands, and nutrient treatments. Plant/soil community feedback was observed with two of the three species and was significantly affected by nutrient enrichment. Addition of fertilizer increased plant productivity and affected plant/soil community interactions. Calcium addition did not affect plant biomass, but was associated with significant increases in fungal colonization regardless of plant species or soil community. In order to test the potential effects of plant seed source by AMF interactions in these same serpentine grasslands, I assessed plant performance of four dominant grasses (*Andropogon gerardii, Sorghastrum nutans, Schizachyrium scoparium, Sporobolus heterolipis*) from local, regional, and non-regional seed sources in serpentine soils with and without serpentine AMF communities. Local *Andropogon, Sorghastrum* and *Schizachyrium* plants out-performed regional and non-regional seed sources when grown in serpentine soil. Addition of the serpentine AMF community enhanced plant growth in these same species. In conclusion, plant/soil interactions are important for structuring these serpentine grasslands, and nutrients or plant genotype have the potential to alter the feedback dynamics.

045. EXTENDING THE ELEMENTAL DEFENSE HYPOTHESIS: LOW LEVELS OF NICKEL MAY DEFEND SERPENTINE *MIMULUS GUTTATUS* FROM HERBIVORY

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Metals accumulated by serpentine plants can defend them against insect herbivores. However, this 'elemental defense' has been demonstrated almost entirely in a few hyperaccumulator species. We tested the hypothesis that metal concentrations below hyperaccumulator levels can defend against herbivory in serpentine tolerant plants that accumulate metals to low concentrations. Using greenhouse experiments, we tested the effect of varying levels of Ni in the soil on the damage inflicted by *Junonia coenia* (Nymphalidae) caterpillars to *Mimulus guttatus* (Phrymaceae) plants. We then tested whether low levels of Ni are toxic to *J. coenia* caterpillars using artificial diet experiments. Amendment of soil with Ni in our greenhouse experiment resulted in elevated Ni levels (40 – 200 μg g^{-1}) in *M. guttatus* plants, but these were well below the levels found in hyperaccumulator plant species (>1,000 μg g^{-1}). Ni-treated plants were significantly more resistant to caterpillar herbivory, as estimated by both plant damage and caterpillar weight gain. For example, Ni concentrations as low as 40 μg g^{-1} reduced caterpillar herbivory of *M. guttatus* plants by 50%. Ni treatment did not affect plant tolerance of caterpillar herbivory. Ni in artificial diet was toxic to *J. coenia* caterpillars at the lowest concentrations tested (218 μg g^{-1} and 467 μg g^{-1}). This study demonstrated that metal concentrations far below those found in hyperaccumulatoring plants can defend serpentine plants against herbivory. We suggest that elemental defenses may be far more common in nature than previously believed and that they may play an important ecological role for a large number of plant species.

046. EVIDENCE OF ADAPTIVE TOLERANCE TO NICKEL IN SERPENTINE ISOLATES OF THE ECTOMYCORRHIZAL FUNGUS *CENOCOCCUM GEOPHILUM*

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We examined *in vitro* Ni tolerance in isolates of the ectomycorrhizal (ECM) fungus *Cenococcum*

geophilum from serpentine and non-serpentine soils to assess whether isolates from serpentine soils exhibited patterns consistent with adaptation to elevated levels of Ni. Isolates of *C. geophilum* from serpentine soils exhibited significantly higher tolerance to Ni than non-serpentine isolates: the mean Ni EC_{50} value for serpentine isolates was approximately seven times higher than the estimated value for non-serpentine isolates. Although there was still a considerable variation in Ni sensitivity among the isolates, the highest EC_{50} value observed for a non-serpentine isolate was nonetheless lower than the lowest EC_{50} value observed among serpentine isolates. This suggests that the serpentine isolates do not simply represent a subset of a 'normal' *C. geophilum* population. Moreover, because isolates from distant geographical origins were screened it is unlikely that results are merely an artefact of local history. Furthermore, all isolates were kept on culture medium without Ni, in some cases for more than five years before the experiments were performed, so that Ni tolerance could not have arisen from physiological adaptation. We also found a negative correlation between Ni tolerance and specific growth rates among isolates, in the absence of Ni. These results suggest that Ni tolerance arose among serpentine isolates as an adaptive response to Ni exposure in serpentine soils. The current study is the first to provide evidence that natural metalliferous soils, such as serpentine, can drive the evolution of metal tolerance in ECM fungi.

047. ECOTYPIC VARIATION IN MORPHOLOGY AND ELEMENTAL CONCENTRATIONS IN THE CALIFORNIAN NI HYPERACCUMULATOR *STREPTHANTHUS POLYGALOIDES* (BRASSICACEAE)

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The Ni hyperaccumulator *Strepthanthus polygaloides* (Brassicaceae) is one of a handful of Ni hyperaccumulators known from continental North America. Considerable variation in morphology and Ni concentrations have been documented from field populations. In this study, we raised plants from ten populations under uniform glasshouse conditions to determine which traits varied due to genetic factors. Morphological data included data on leaf form (length, width and metrics reflecting the depth and width of leaf lobes) and plant size (height to first flower as they bolted in summer). Phenology was documented by noting flowering timing of plants. Elemental concentrations of plants were also determined for 10 elements. Populations varied significantly for all morphological/phenological traits. Populations also varied significantly in concentrations for all elements (including Ni), although all populations hyperaccumulated that element. We conclude that there is considerable genetic divergence between populations, likely due to the insular nature of serpentine soil outcrops in California. This divergence may justify taxonomic subdivision of *Strepthanthus polygaloides*.

048. THE EFFECT OF FIRE ON SERPENTINE PLANT COMMUNITIES AT SIERRA ALTA DE AGABAMA, VILLA CLARA, CUBA

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Fires are considered among the most common disturbances for the serpentine plant communities of Cuba. However, their overall effects on the community are controversial. In this work, we compare diversity, species composition, vegetation structure, fuel (dead biomass) loads and fuel distribution between burned and unburned sites at Sierra Alta de Agabama, Villa Clara, Cuba. The species diversity is significantly lower in the burned sites than in the unburned ones but the burned sites contain native non-serpentine species and also non-native species that contribute to an increase in the overall richness of the region. The biomass on the unburned sites is mostly allocated to the shrub layer but in the burned sites it is distributed in the herb layer. Fuel loads are significantly bigger in burned sites than in unburned ones and fuel distribution within the sites is less variable in the burned sites than in unburned ones.

049. PARALLEL EVOLUTION AND CONVERGENT PHYSIOLOGICAL TOLERANCE MECHANISMS OF SERPENTINE-TOLERANT *ACHILLEA MILLEFOLIUM* (ASTERACEAE) EDAPHIC ECOTYPES

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Serpentine soils have exceedingly low Ca:Mg mol ratios (« 1.0), compared to nonserpentine soils. Ca is a plant-essential macronutrient that is important for cell wall structural integrity and growth. Serpentine-tolerant plant physiological adaptations to low soil Ca:Mg mol include selective Ca uptake, Mg exclusion or both. Although serpentine tolerance and its implications for speciation have been widely studied utilizing congeneric serpentine-tolerant and non-tolerant species, there has been little study of the potential for the independent origin of serpentine-tolerant ecotypes (ecotypic convergence) within the same species. In this study, nonserpentine and serpentine *Achillea millefolium* (Asteraceae) ecotypes collected from widespread locations in the western and eastern USA, Newfoundland, UK and Austria were examined for seedling tolerance to serpentine soil (Ca:Mg mol = 0.2) and shoot and root Ca and Mg uptake when grown under uniform soil nutrient conditions (Ca:Mg mol = 1.0) in order to determine if there is evidence for serpentine ecotypic convergence. Results revealed several examples of serpentine ecotypic convergence with strong evidence of directional selection for enhanced Ca uptake and root-to-shoot translocation across all of the serpentine ecotypes. This study

demonstrated that serpentine-tolerant ecotypes of *Achillea millefolium* have arisen independently multiple times and that the genetic preadaptation for serpentine tolerance (selective Ca uptake) in the species is fixed.

050. CLIMATE CHANGE AND SERPENTINE PLANTS: A CONCEPTUAL FRAMEWORK

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Serpentine endemics, and other edaphic endemics, contribute disproportionately to the world's botanical diversity. We are interested in whether they face heightened risks of extinction from climate change, either because they are more sensitive to climate *per se,* or because their confinement to localized areas of special substrates limits their ability to shift their ranges. We present a conceptual model predicting the responses of endemics versus non-endemics to altered rainfall. We also review existing evidence on how endemics and non-endemics respond at the species and community levels to geographic gradients in climate. In a subsequent talk (to be presented by author #2), we will present evidence from a historic *vs*. modern comparison of serpentine and non-serpentine plant communities.

051. HAVE 55 YEARS OF CLIMATE CHANGE AFFECTED SERPENTINE AND NONSERPENTINE PLANT COMMUNITIES DIFFERENTLY?

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Plant species associated with serpentine may be more likely to go extinct due to climate change than closely related species on non-serpentine soils (evidence presented by author #2 in a previous talk). We examine c. 55 years of climate change impacts on plant communities associated with serpentine and non-serpentine soils by re-sampling areas originally sampled by Robert Whittaker from 1949-1951 in the Klamath-Siskiyou mountains in Oregon. We determine how serpentine and non-serpentine plant distributions have changed over 55 years and evaluate whether extinction risk is higher for plants on serpentine *vs*. non-serpentine soils.

052. PHYLOGENETIC ANALYSIS OF THE INFRASPECIFIC TAXA, *ERIGERON THUNBERGII*, DISTRIBUTED IN ULTRAMAFIC ROCK SITES

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Erigeron thunbergii A. Gray is an infraspecific taxon that is locally distributed in serpentine, peridotite, limestone, and non-ultramafic sites in high mountains, as well as on meadows and seashores in Japan. This plant contains a broad range of variation in floral traits at the intraspecific taxonomic ranks. Morphological traits such as leaf and flower size and flower color of plants in ultramafic sites are diverse and distinguishable from those of plants in non-ultramafic sites. However, the relationships among these infraspecific taxa are not well understood phylogenetically, and have not been used to explain their distributional patterns. Thus we aimed to determine the evolutionary patterns of plants and performed molecular phylogenetic analyses. Using data derived from sequencing the internal transcribed spacer (ITS1, 5.8S ribosomal DNA, and ITS2) regions of nuclear ribosomal DNA, nineteen ITS types of *E. thunbergii* were identified and showed strong geographical structure. Especially specific ITS types on specific soil were detected. We identified Clade 1, which was composed of populations from Hokkaido Island and the northeast Honshu district group, and Clade 2, which was comprised of populations from central Honshu Island and seashores in the Sea of Japan. The phylogenetic tree showed the possibility of two major *Erigeron* phylogenies, *i.e.* from the Kamchatka Peninsula and the Chinese continent.

053. SOIL NICKEL INFLUENCES SURVIVORSHIP, GROWTH AND REPRODUCTION OF THE SERPENTINE HYPERACCUMULATOR SPECIES, *ALYSSUM MURALE* WALDST AND KIT. (BRASSICACEAE)

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Alyssum murale is a nickel hyperaccumulator found on serpentine and non-serpentine soils throughout the Mediterranean. Ecologists generally expect that metals play a role in discouraging herbivory on shoots of hyperaccumulators. This report outlines a series of studies exploring the influence of soil nickel on wider aspects of growth and reproduction in *A. murale*. In a two-year

study at UVA's Blandy Research Station in Boyce, VA we compared growth and reproduction in a field array of plants grown on soil amended with 500 mg kg^{-1} Ni (1:1 Ni acetate: Ni sulfate) or soil without added nickel. Vegetative growth of plants in nickel-amended soil was greater (p = 0.004) and survivorship was higher in nickel-amended soil (92% with nickel, 68% without nickel). Plants in nickel-amended soil had more trichomes on leaves (p = 0.001) and fruits (p <0.001). *A. murale* attracted generalist pollinators (mainly sweat bees and hoverflies) at this field site. A pollinator choice study revealed no preference for visiting plants on either soil type, but sweat bees spent more time on flowers of plants without nickel (p = 0.02). Plants on soil with nickel produced significantly larger fruits (p <0.001) and heavier seeds (p = 0.02). In a greenhouse study, seeds of predetermined weight were germinated and grown without competition for 6 weeks on soil with or without nickel (500mg/kg). Seed weight and soil nickel both had significant positive effects on seedling shoot biomass (p = 0.04; p <0.001) and root biomass (p = 0.008; p< 0.001).

POSTER PRESENTATIONS

054. DIGESTION AND ELEMENTAL DISTRIBUTION IN LARVAL AND IMAGINAL STAGES OF *STENOSCEPA* SP., A GRASSHOPPER ASSOCIATED WITH NI-HYPERACCUMULATING PLANTS

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Stenoscepa sp. (Orthoptera), South African grasshopper, lives on Ni-hyperaccumulating plants (e.g. *Berkheya coddii, B. zeyheri, Senecio coronatus*). The aim of this study was to find adaptation of digestion to extremely high nickel doses in grasshopper's food. The analyses of digestive enzyme (α-amylase, disaccharidases, specific glycosidases, total proteolytic activity, trypsin and aminopeptidase) activity as well as the distribution of metals (Ni, Fe, Mn, Zn, Cu and other) by micro-PIXE and AAS methods in the gut of 2nd-instar larvae and adult male and female of *Stenoscepa* sp. were performed. The analysis of Ni concentration in *Stenoscepa* sp. showed the highest Ni level in the gut. High Ni concentration was found in larvae and females (over 1000 μg g^{-1}, and over 2000 μg g^{-1}, respectively), while in males the value was lower (up to 682 μg g^{-1}). Nickel concentration in body walls, gonads and brains was about ten times lower than in the gut, while in faeces Ni contents reached 11,280 μg g^{-1}. This may suggest that the grasshoppers feeding on nickel hyperaccumulators excrete toxic metals. This is probably due to

ineffective food assimilation and increased food intake, what may be proved by the pattern of digestive enzymes activity: very high amylase activity (up to 95 µmol maltose/min/mg protein) and high activity of disaccharidases (saccharase, maltase and cellobiase). Among specific glycosidases, α- and β-glucosidase played an important role, while the activity of α- and β-galactosidase was low. Total proteolytic activity oscillated around 100 J.A./min/mg protein/ml and did not differ between developmental stages.

055. IS THERE EVIDENCE OF ADAPTATION TO SERPENTINE SOILS IN SCOTTISH POPULATIONS OF *ARABIDOPSIS LYRATA*?

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Understanding local adaptation is essential for making predictions about the response of ecosystems to environmental change. Given their commonly limited distribution and high selective impact, serpentine soils represent an excellent model system for studying local adaptation processes. This study assessed the local adaptation of *Arabidopsis lyrata* subsp. *petraea* to serpentine soils, by sampling individuals from three pairs of serpentine and non-serpentine sites distributed across Scotland (Shetland, Cairngorms and the Isle of Rum). Seedpods of at least 20 individual plants and associated soil for a sub-sample of two to five individuals were sampled from these sites. Seeds were grown under serpentine-like and non-serpentine-like chemical treatments in the laboratory. Analysis of soil chemistry and mineralogy were used to inform treatments for seedling growth. Measurements of germination success, morphology, phenology and physiology were made in order to assess whether populations are locally adapted to their native soil type and whether local adaptation is similar in different serpentine environments. I will discuss how this work informs our understanding of the nature of adaptation of this species to serpentine soils, at both local and national levels.

056. LEAF TISSUE STABLE ISOTOPES IN NINE TREE SPECIES ALONG TWO ENVIRONMENTAL GRADIENTS WITHIN SUSUA STATE FOREST, PUERTO RICO

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Stable isotopes for carbon, nitrogen and oxygen were evaluated for bulk leaf tissue collected from nine tree species at multiple locations along precipitation and soil depth gradients on ultramafic bedrock within the Susúa State Forest, Puerto Rico. Patterns within the carbon and oxygen isotopes were used to examine water stress and its relation to biomass; nitrogen content and isotopic composition was used to assess nitrogen use efficiency and nitrogen source for the tree species. The physiology of carbon uptake results in a strong correlation between ^{13}C and the relative water deficit the plant experiences; results from this study reflect this pattern across the precipitation and soil depth gradients, a proxy for soil water storage, although some species were non-responsive. ^{18}O has been used as a proxy for leaf transpiration, but bulk leaf tissues in this study did not show a pattern consistent with water availability. ^{15}N patterns suggest that ridgetop areas use atmospherically-derived nitrogen, whereas alluvial areas are more depleted, indicating more nitrogen derived from organic sources is used by trees in these areas. Nitrogen content varied three-fold among species, with low-content species associated with ridgetop environments, but overall, nitrogen was only weakly correlated with species biomass or soil nitrogen content.

057. EVOLUTION OF SERPENTINE ENDEMISM IN FIRE-PRONE HABITATS: A PRELIMINARY MODEL FROM CALIFORNIA'S CHAPARRAL

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In fire-prone habitats plants are subjected to recurring ecological disturbance. Many fire-adapted shrubs can be broadly categorized into two groups: those that survive fire and re-establish by resprouting from underground structures and those that are killed by fire and recruit from seed. Characteristics of the fire regime play a central role in determining plant community composition with respect to the two strategies; key among these characteristics is the fire interval. It is hypothesized that short intervals between fires promote success of resprouters while long intervals favor the reseeders. California's fire-prone serpentine chaparral exhibits a relatively long fire interval, due to slow biomass accumulation as a result of the low productivity typical of serpentine habitats. We hypothesize that in fire-prone serpentine chaparral a higher rate of endemism will be observed among the obligate seeding shrubs compared to the resprouting shrubs, and that the majority of serpentine endemic shrubs will be obligate seeders. This hypothesis is logical, as an elevated level of speciation is expected among obligate seeders due to generation time curtailment. We propose a preliminary scenario that can provide a context for

future studies on the evolution of serpentine endemism among shrub species in fire-prone habitats.

058. INVESTIGATING THE MAINTENANCE OF DIVERSE ARBUSCULAR MYCORRHIZAL FUNGAL COMMUNITIES

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By forming associations with plant roots, arbuscular mycorrhizal fungi (AMF) acquire carbon from their hosts and, in return, improve nutrient or water uptake or provide protection from pathogens or heavy metals. We understand little about the factors shaping the diversity of AMF on a single host plant and how that diversity influences plant performance. It is possible that co-occurring AMF species provide different functions to the host or that different AMF species can tolerate different ecological conditions so that the plant relies primarily on different species in different environments. Naturally heterogeneous serpentine soils serve as a model system to investigate these possibilities. Because AMF species can be non-additive in their effects on plant growth, we propose to measure the function of a particular AMF species by examining plant performance after deleting it from the community. We use this method in a greenhouse experiment to evaluate the roles of five AMF species from a natural community on serpentine soil. By repeating this design in soils differing in nitrogen, phosphorus, and nickel we can determine if different AMF species provide different services to the plant. We use two host grass species from the same Eastern U.S. serpentine site, *Andropogon gerardii* and *Sorhastrum nutans*. We find that AMF species with a neutral or negative effect under one soil condition can promote plant growth in another, suggesting that community diversity is useful in coping with heterogeneous soils and offering an explanation for why any one plant species supports several species of these fungi.

059. THE COMPETITIVE ABILITY OF A SERPENTINE NICKEL HYPERACCUMULATOR (*ALYSSUM MURALE)* UNDER VARYING NUTRIENT CONDITIONS

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The role of edaphic factors in influencing competitive ability of serpentine species has long been of interest to plant ecologists. *Alyssum murale* (Brassicaceae) is a nickel-hyperaccumulating species found in serpentine areas throughout the Mediterranean. It is not restricted to serpentine soils, however. This study focuses on the effect of varying nutrient conditions on the competitive

ability of populations of *A. murale* from Albania and Bulgaria in non-serpentine soils. The objective of this study was to determine how well *A. murale* would grow in competition with perennial ryegrass (*Lolium perenne*) on a non-metalliferous soil with varying soil nutrients. For each population, 288 pots were set up as pure treatments (20 *Alyssum* seeds per 2.5 inch pot) or mixed treatments (10 *Alyssum* seeds + 10 *Lolium* seeds). Pure and mixed pots were fertilized with three nutrient treatments (0mg L^{-1}, 62 mg L^{-1}, 113 mg L^{-1} 15:30:15 NPK plus micronutrients) at three week intervals. Germination and growth was monitored; after 11 weeks plants were harvested, dried and weighed. Results were analyzed by 2-way ANOVA for effects of planting treatment and nutrient level. *Alyssum* showed a significant negative effect of competition; plant height and shoot biomass were significantly lower in mixed pots compared to pure pots (p <0.001). Although *Lolium* showed significant growth increases with increased nutrients, shoot biomass of *Alyssum* did not respond to increased nutrients. The results of this study indicate that the competitive ability of plants in these two populations of *A. murale* is low and does not change with varying soil nutrients.

060. THE EVOLUTION OF SERPENTINE TOLERANCE IN THE *MIMULUS GUTTATUS* SPECIES COMPLEX

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The *Mimulus guttatus* species complex presents an opportunity to investigate a number of questions about the evolution of serpentine tolerance and speciation. *Mimulus guttatus* grows both on and off serpentine soils throughout California and Oregon and is the presumed progenitor of two serpentine endemics: *M. nudatus* and *M. pardalis*. We are interested in understanding the genetic basis of serpentine tolerance in the *M. guttatus* species complex as well as the role of adaptation to novel edaphic conditions in driving speciation of *M. nudatus* and *M. pardalis*. We have shown that there are differences in tolerance to low calcium-magnesium ratios in the *M. guttatus* species complex. Specifically, we have found local adaption; there is a tradeoff wherein serpentine populations grow best in low Ca:Mg conditions and non-serpentine populations grow best in high Ca:Mg. We plan to use QTL mapping to determine the genes underlying these differences. We would also like to investigate additional edaphic factors characterizing serpentine soils and their possible roles in promoting reproductive isolation between species within the *M. guttatus* species complex.

SESSION: *PHYSIOLOGY & GENETICS*
MODERATOR: JOE POLLARD

PROFESSOR AND CHAIR, DEPARTMENT OF BIOLOGY
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ORAL PRESENTATIONS

061. LOCALISATION OF NICKEL IN TISSUES OF *STREPTANTHUS POLYGALOIDES* GRAY (BRASSICACEAE), AN ENDEMIC CALIFORNIAN NICKEL HYPERACCUMULATOR

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The Brassicaceae contains a large number of nickel hyperaccumulator plant species. This family includes several genera such as *Arabis*, *Thlaspi*, *Streptanthus*, etc., well represented in the ultramafic flora of western North America. One of the most typical indicator genera in these areas is *Streptanthus* Nutt., an American genus which must have evolved *in situ*. This genus contains taxa endemic to, or tolerant of, ultramafic soils. The hyperaccumulation of nickel in *Streptanthus* species was first reported in the Californian ultramafic endemic *Streptanthus polygaloides* Gray. *S. polygaloides* is a therophyte which is strictly confined to ultramafic soils throughout the Californian Sierra Nevada foothills. Its distribution ranges from meso-Mediterranean to supra-Mediterranean thermotype territories. In these areas, it defines specialised annual plant communities developing on ultramafic talus and barrens. Different plant organs of some *S. polygaloides* populations were selected for elemental microanalysis by Inductively-Coupled Plasma Mass Spectroscopy (ICP-MS). The roots, stems, leaves, flowers, and fruits were analysed for Ni accumulation and metal localisation. The different plant tissues were analysed by scanning electron microscopy coupled with an energy-dispersive X-ray probe (SEM-EDX). Elemental mapping of the studied tissues was also compared.

062. COMPARISON OF NI-ELIMINATION STRATEGIES IN REPRESENTATIVES OF TWO FAMILIES OF BEETLES FEEDING ON THE NI-HYPERACCUMULATING PLANT *BERKHEYA CODDII*

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Berkheya coddii (Asteraceae), a plant with extremely high amounts of Ni (up to 7.6% dry mass in leaves) has its own insect consumers. They are Ni-tolerant and use various adaptive mechanisms. Such adaptations are physiologically costly and ecotoxicologists should know how effective the trade-off mechanisms are in different groups of insects competing for the same food sources. In former studies the micro-PIXE method has been used to investigate adaptation of a chrysomelid beetle, *Chrysolina pardalina* and to prove our hypothesis that Ni might replace Zn in the tubular space, bound to sulphur- and nitrogen-bearing ligands in the Malpighian tubules. Recently we found another *B. coddii* feeder, *Epilachna* cf. *nylanderi*, a folivore coccinellid beettle. The life cycle of this species was observed in the field and in laboratory conditions. In this study we combined micro-PIXE quantitative elemental mapping in organs of the same organism responsible for metal transfer, bioaccumulation or bioelimination (parts of the digestive tract and Malpighian tubules) with TEM morphological studies in order to compare what mechanisms are used by both species to cope with excess Ni. Comparisons of functional aspects of target organs and quantification of Ni data from selected micro-areas of these organs demonstrated a distinct similarity of detoxification mechanisms used by both species against Ni. However, we found many differences between them depending on site interactions of Ni in various parts of the gut and Malpighian tubules. Zn and Ca are the main competing elements important for Ni bioelimination, while the role of Mn and Cu is not significant.

063. SERPENTINOMICS—AN EXCITING NEW FIELD OF STUDY

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Serpentinomics, the use of genomic data to understand the evolutionary ecology of serpentine endemism, is an emerging field of study. Using the rapidly developing tools for genome-wide analysis in non-model plant species, we can begin to understand the genetic basis for adaptation to serpentine soils. Herein, we focus on a non-model California annual plant, *Collinsia sparsiflora* (Plantaginaceae/Veronicaceae), in order to demonstrate the utility of genome-scale investigation into the evolutionary transition to serpentine soils. Our previous studies at six focal populations at McLaughlin Natural Reserve (north coast range, CA) convincingly demonstrate local adaptation between serpentine and adjacent non-serpentine populations amidst gene flow at neutral molecular markers, predictable niche preference and subsequent reproductive isolation between edaphic races of *C. sparsiflora*. We are now surveying for genomic "islands" of differentiation between these six focal populations through AFLP-based F_{ST} outlier analysis. Furthermore, *C. sparsiflora* can be found in serpentine and non-serpentine soils across its geographic range from southern California to southern Oregon. By comparing genomic islands of differentiation among paired serpentine and non-serpentine populations across the species range, we will be able to determine the degree of molecular convergence during repeated adaptations to serpentine soils. A complementary phylogeographic analysis across the species range will also shed light on the population-level history of adaptation to serpentine soils in this species.

064. CHARACTERIZING SERPENTINE TOLERANCE IN *MIMULUS GUTTATUS* (PHRYMACEAE)

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Six populations of *Mimulus guttatus*, three serpentine endemic and three non-serpentine, were used to examine divergence between populations from different soil types as well as among populations within the same soil type (15 maternal lines for each population, one individual per maternal line). Morphological and phenological traits were measured in a common greenhouse environment. Above and below-ground Ca, Mg, and biomass dynamics were also measured in

response to different hydroponic treatments. Two treatment extremes (Ca:Mg ratio of four and 0.01) were chosen to discern divergence between serpentine and non-serpentine populations. Two cuttings per plant were grown, with one cutting placed in each treatment solution. Tissue concentrations of Ca and Mg were determined using Neutron Activation Analysis. Evidence was found that populations of *M. guttatus* are diverged according to soil type for traits that fit a pattern of local adaptation. Serpentine adapted *M. guttatus* had smaller flowers and leaves than non-serpentine M. guttatus. Serpentine and non-serpentine populations also responded differently to hydroponic treatment. In both environments serpentine endemics had significantly higher foliar Ca:Mg ratios as compared to non-serpentine individuals. The root tissue of both serpentine and non-serpentine plants did not show the same selectivity for Ca over Mg. Comparison of above and below ground responses suggests a possible mechanism for serpentine soil adaptation.

065. CELLULAR LOCALIZATION AND DISCRIMINATION OF COBALT AND NICKEL IN *HAUMANIASTRUM ROBERTII, CROTALARIA COBALTICOLA* AND *ALYSSUM MURALE* USING MICROPIXE SPECTROMETRY

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Plants that can survive on metalliferous soils offer opportunities to investigate the underlying mechanisms of metal tolerance and adaptation to nutritionally unfavourable substrates. Two plant species that are endemic to the Copper Arc and the Copperbelt regions of south-central Africa, *Haumaniastrum robertii* and *Crotalaria cobalticola,* and a typical Eurasian serpentine plant, *Alyssum murale,* were used to compare elemental mapping and cellular localization of cobalt and nickel in their leaves by using microPIXE spectrometry. The plants were exposed to an aerated hydroponic nutrient solution with both cobalt and nickel for 6 weeks. Elemental concentrations in the plant tissues were determined by ICP-OES. Leaf samples for PIXE analyses were prepared by cryo-fixation in liquid nitrogen and freeze-drying, and then hand-sectioned under a dissection microscope. The results showed that all plant species tested could hyperaccumulate both cobalt and nickel. The concentrations of cobalt and nickel in the shoots were all greater than those in the roots. Both cobalt and nickel were present predominantly in vascular and epidermal tissues in the leaf cross-sections of *H. robertii* and *C. cobalticola* but only in the epidermis in leaves of *A. murale.* PIXE images from surface scanning showed uniform nickel distribution in the leaves of *A. murale* and preferential localization of cobalt near leaf tips/margins, in contrast to uniform nickel and cobalt distributions in the leaves of *H. robertii* and *C. cobalticola*.

066. NI^{2+} REQUIREMENT OF *ALYSSUM* SPECIES SUPPLIED UREA-N.

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Ni is essential for all plants due to its role in urease. Many *Alyssum* species are known to hyperaccumulate Ni to over 20 g kg^{-1} while normal plants require only about 0.1 mg kg^{-1} dry matter. As part of our research on Ni hyperaccumulation by plants, we conducted experiments to measure the activity of free Ni^{2+} required for growth of *A. murale*, *A. corsicum*, *A. montanum* and tomato grown in a modified Hoagland nutrient solution with 2 mM Mg and 1 mM Ca to simulate serpentine soil solutions. We used chelator-buffered nutrient solution to control the activity of free ions of the micronutrient cations. In the first experiments we used hydroxyethylethylene-diaminetriacetate (HEDTA) to achieve Ni^{2+} levels as low as 10^{-15} M. With urea-N supply the plants did not grow after transfer to the low Ni solutions, while nitrate-grown plants thrived. Symptoms agreed with urea toxicity/Ni deficiency. We had to add additional Ni to obtain growth with the HEDTA system and estimated the requirement at $10^{-11.9}$ M Ni^{2+} for normal growth with urea-N. *A. montanum* behaved similarly to the hyperaccumulators. Another experiment was conducted using cyclohexane-ethylenediaminetetraacetate (CDTA) to supply higher levels of buffered Ni^{2+} and better cover the range of the requirement estimated from the first experiment. Results of the second experiment will be reported, as will other interesting new findings from our basic studies on Ni hyperaccumulator species.

POSTER PRESENTATIONS

067. MORPHOLOGICAL AND ISOENZYMATIC DIFFERENTIATION OF *GUETTARDA CALYPTRATA* (RUBIACEAE) IN ULTRAMAFIC AND LIMESTONE SOILS IN CUBA

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The differentiation of ecotypes in extreme soils is an important step in the evolution of plant species. This process might be one of the main causes for the diversification of the Cuban flora. In this work we compare two populations of *Guettarda calyptrata* A. Rich. (Rubiaceae), one from the ultramafic outcrops of Lomas de Galindo and the other from the limestone area at Las

Cuevas, both located in Havana province. The morphological variables tested were: stem diameter, plant height and the area of the leaves. We also made an electrophoretic study in polyacrylamide gel (PAGE) for two isoenzymatic systems, peroxidase and polyphenol oxidase, using the extracts of the leaves. The differences in the stem diameter and plant height were significant but the area of the leaves did not differ between populations.

068. ULTRASTRUCTURAL FEATURES OF ROOT TISSUES OF NI-HYPERACCUMULATING AND NON-ACCUMULATING GENOTYPES OF *SENECIO CORONATUS* (THUNB) HARV. (ASTERACEAE)

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In a previous study (Mesjasz-Przybylowicz 2007; *Plant and Soil* 293: 61-78), root cytology at the light microscope level and elemental distribution using a nuclear microprobe were examined in two genotypes of *Senecio coronatus* growing on ultramafic outcrops. Cytological differences were found in inner cortical cells and exodermis and a higher concentration of Ni was present in root tissues of the hyperaccumulator. The present investigation extends the previous study and focuses on ultrastructural features of root tissues of both genotypes. Distinct groups of inner cortical cells of the Ni-hyperaccumulator possessed large nuclei and an organelle-rich cytoplasm. An extensive network of endoplasmic reticulum (ER) cisternae permeated throughout the cytoplasm. Numerous ribosomes, microbodies, mitochondria, Golgi, microtubules, membranous vesicles and lipid-like spherical bodies were also present. Distinct cell groups were not found in the inner cortex of the non-accumulator and cells here had smaller nuclei, a thin parietal cytoplasmic layer and few of the organelles present in cells of the hyperaccumulator. Various cytoplasmic organelles are implicated in the formation of secondary metabolites found in both genotypes. Significantly larger amounts of secondary metabolites accumulate in the hyperaccumulator compared to the non-accumulator due to the presence of an extensive organelle-rich cytoplasm in the former. Exodermal Casparian bands of the non-accumulator were better defined at the ultrastructutral level compared to those of the hyperaccumulator giving further support to the earlier study that the bands may be functionally different from those of the hyperaccumulator and may limit the entry of Ni into roots of the non-accumulator.

069. NICKEL AND CALCIUM LOCALISATION IN FRUIT AND SEED OF THE METAL HYPERACCUMULATOR *GEISSOIS PRUINOSA* VERSUS THE NON-HYPERACCUMULATOR *G. MONTANA*

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New Caledonia is known to possess one of the largest diversities of Ni-hyperaccumulator species occurring on serpentine soils. Investigations, into the distribution of nickel in several organs of these kind of plants have shown the leaves to be the main sinks of the metal. However, fruits as well have also sometimes revealed to be rich in metal. There is a lack of information on the presence of nickel in seeds. In the course of studying seeds of several endemic plants from New Caledonia used for revegetation, we chose to compare the structure and chemical composition of two *Geissois* (Cunoniaceae) species, *G. pruinosa* and *G. montana.* The former, which grows on ultramafic rocks, is a Ni-hyperaccumulator, whereas the latter, from metamorphic soils, is not. Scanning electron microcopy and x-ray microanalysis were used to study the distribution of different minerals and to localise nickel, in particular in young fruit (bilocular capsule) of *G. pruinosa* and seed of both plants. Crystals of nickel were detected within the fruit tissues (*G. pruinosa*) but on the contrary not in the seed (both *Geissois* species). These results are similar to those obtained on the New Caledonian hyperaccumulator *Psychotria douarrei* (Rubiaceae). Calcium is found in oxalate crystals in both species at the same localisations. Concentration, localisation and utility of these two minerals are discussed in relation to the plants' environment and reproductive functions.

070. ARE NICKEL HYPERACCUMULATOR PLANTS TOLERANT TO COPPER?

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Nickel hyperaccumulators have characteristics that enable them to hyperaccumulate Ni in their shoots. More efficient antioxidant activities and constitutively high production of histidine in their roots are among these properties. Histidine chelates Ni in the root and transfers it to the shoot. Copper is an essential and potentially toxic element for plants. Histidine is a chelator for Cu, too, and it is transferred to the shoot as His-Cu complex. In this experiment, in a fully randomized block design in pots and using solution culture in perlite in the greenhouse, we determined the tolerance of an Iranian serpentine Ni hyperaccumulator plant *Alyssum inflatum* to

Cu. We used different concentrations of Cu (0.2, 2, 20 and 50 μM) in the presence (100 μM) and absence of Ni. Also we determined catalase and ascorbate peroxidase activity in the root and shoot. Results show that plants in the absence of Ni are quite resistant to Cu until 20 μM and there is an increase in growth at 2 μM Cu. In the presence of Ni, tolerance to Cu is less. Also the shoot Cu content in the presence of Ni is less. We observed an increased growth in the presence of Ni when the Cu concentration was low. The activity of catalase and ascorbate peroxidase in the toxic levels of Cu decreased in both root and shoot and the most activity of these enzymes was found at 2 μM Cu both in presence and absence of Ni.

071. EFFECTS OF NI ADDITION AND FERTILIZATION ON *FESTUCA BRIGANTINA* GROWTH AND MYCORRIZAL COLONIZATION

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Festuca brigantina is an endemic grass of serpentine areas in NE Portugal. Low translocation of Ni in this species is probably a strategy to withstand the high soil Ni concentration. However, low levels of essential nutrients represent another important constraint factor in serpentine soils. The aim of this work was to investigate the effect, and possible interaction, between Ni addition and fertilization in the growth and mycorrhizal colonization of *F. brigantina*. Seedlings were planted in serpentine soil with three levels of Ni addition (0, 20 and 50 ppm Ni) and two levels of fertilization (fertilized/non-fertilized), in a total of 6 treatments. Nickel was added to the soil as $NiSO_4.6H_20$ before the beginning of the experiment and four new applications were carried out after week 25. Fertilization, with a modified Hoagland solution, was applied weekly throughout the experiment. Plants were grown under controlled conditions for 36 weeks, after which plant growth parameters and mycorrhizal colonization levels were assessed. The addition of increasing levels of Ni to the soil did not affect *F. brigantina* survival but induced a decrease in plant growth. At each Ni level, fertilization ameliorated the Ni-induced effects. Mycorrhizal colonization was reduced both by Ni and fertilization. These results are in agreement with other research work carried on several serpentine areas indicating that nutritional stress can be more relevant for the development of serpentinophyte species than high Ni concentration in the soil.

072. NICKEL ACCUMULATION BY *FIMBRISTYLIS OVATA* (CYPERACEAE) GROWING ON ULTRAMAFIC SOIL IN USSANGODA, SRI LANKA

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Nickel (Ni) accumulating plants are commonly found on ultramafic soils. Of the Ni accumulating species on the ultramafic soil in Ussangoda, *Fimbristylis ovata* (Cyperaceae) is fast growing and easily propagated. It has a stunted growth habit with a shoot/root ratio of 0.23 which when grown on non-ultramafic soil increased to 1.52. The plant-available Ni content in the soil was variable (84-170 ppm). Ni uptake in the ultramafic soil is determined by available Ni, soil moisture regime, and other soil chemical characters which influence uptake by the roots. *F. ovata* plants were grown under experimental hydroponic conditions to determine the translocation, uptake and tolerance to Ni under different concentrations. Plants grown in hydroponic solution supplemented with 100-900 μM Ni for two weeks accumulated over 3000 μg g^{-1} dw of Ni, of which 30% was found in the shoots. In a time-course study, over 50% of the Ni was taken up by the roots in the first 24 hours, reaching a peak after 3 days. The transfer of the absorbed Ni to the shoots reached a maximum after 5 days. *F.* ovata is able to hyperaccumulate and tolerate Ni in its tissues. Although *F. ovata* accumulated low levels of Ni on the ultramafic soil, it was able to uptake much higher levels under experimental conditions.

073. MANGANESE HYPERACCUMULATION IN *PHYTOLACCA AMERICANA*

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Hyperaccumulation of metallic elements to exceptional concentrations in plant tissues is a rare phenomenon, reported for nine elements and approximately 450 plant species. Most known cases involve species that are restricted to metal-enriched soils. Researchers in China recently found that *Phytolacca acinosa* growing on manganese-polluted soils can hyperaccumulate manganese, and further showed that plants from normal soils also possess the ability to hyperaccumulate this element. Because the genus *Phytolacca* is taxonomically small, we chose to investigate whether ability to hyperaccumulate manganese might exist in another species, not known to occur on manganese-enriched sites at all. *Phytolacca americana* (pokeweed) is a ubiquitous weed of roadsides and disturbed areas in the southeastern USA. Field-collected samples from Greenville, SC contained approximately 2000 μg g^{-1} Mn on a dry-weight basis, while other species from the same site ranged from 50 to 450 μg g^{-1}. Seedlings of *P. americana* were transplanted to the laboratory and grown hydroponically in nutrient solutions ranging from 15 μM to 8 mM Mn. After three weeks in the most concentrated Mn solution, the average Mn concentration in leaves was over 32,000 μg g^{-1} or 3.2%. This clearly qualifies *P. americana* as a hyperaccumulator of manganese. We believe that this is the first case where latent physiological ability to hyperaccumulate a metal has been discovered in a species not known to associate with that metal in nature. Future studies will attempt to find populations of *P. americana* on Mn-enriched soils, to determine whether the property is ever expressed in the field.

074. TOLERANCE, UPTAKE AND ACCUMULATION OF COBALT BY *ALYSSUM BRACTEATUM*, AN ENDEMIC IRANIAN NI HYPERACCUMULATOR

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Serpentine soils contain relatively high concentrations of Ni, Co and Cr. A number of serpentine plants are able to accumulate extraordinary concentrations of Ni in their leaves. In temperate regions, most of the Ni hyperaccumulators belong to the family Brassicaceae, the largest number being in the genus *Alyssum* (more than 50 taxa). Only one case appears to have been recorded of Co hyperaccumulation on serpentine soils. There are substantial areas of serpentine soils at many locations in Iran. *Alyssum bracteatum* is endemic to Iran and the first Ni hyperaccumulator reported from this species. During this study uptake and accumulation of Co by populations of this species collected from serpentine and non-serpentine soils were tested under controlled conditions. Seedlings of *A. bracteatum* were grown in different concentrations of 0, 50, 100, 250 and 500 μM in solution culture (perlite) for 21 days. The tolerance of serpentine populations to Co was significantly higher than those in non-serpentine populations. Analysis of shoots showed that the amounts of Co in all populations of *A. bracteatum* increased with increasing Co in solution culture. Serpentine populations of *A. bracteatum* can contain 1830 μg Co g^{-1} when growing under concentration of 250 μM Co in solution culture. The amounts of Co in the shoots of non-serpentine populations were significantly lower than those in serpentine populations. In conclusion, the serpentine populations of *A. bracteatum* are able to tolerate and accumulate more Co compared to non-serpentine populations.

075. SERIES STUDIES ON THE JAPANESE NI-HYPERACCUMULATOR *THLASPI JAPONICUM* AND ITS HEAVY METAL TRANSPORTERS ZNT1/2

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Thlaspi japonicum (Brassicaceae) inhabiting Mt. Yubari is the sole Ni hyperaccumulator in Japan at present. This plant accumulates Ni up to 2500 mg kg^{-1} in its shoot (Mizuno *et al*. 2003). In dimethylglyoxime-stained *T. japonicum* leaves, Ni was observed as rod-shaped compound crystals, mainly around the stomata and the projections of the leaf edge. In addition, a considerable amount of Ni was excreted via guttation fluid (0.67-1.33 mg L^{-1}). This plant is not a

serpentine-endemic plant, but *T. japonicum* plants from two non-serpentine areas also could accumulate Ni when cultivated on ultramafic soil, suggesting that *T. japonicum* is able to accumulate Ni regardless of ecotype and habitat (Mizuno *et al*. 2005). In metal hyperaccumulator plants, a variety of ZIP (Zinc/Iron-regulated transporter like Protein) transporters are highly expressed for maintenance of metal homeostasis and work as the key factors for metal hyperaccumulation. Previously we cloned two ZIP transporter genes (*TjZNT1*/*2*) from *T. japonicum*, and reported that these transporters conferred high Ni tolerance to yeast cells (Mizuno *et al*. 2005). The ion specificity and Ni tolerance level of TjZNT2 are distinctly different from TjZNT1, even though both transporters share high sequence homology. We confirmed subcellular localizations of these transporters in yeast cells by green fluorescence protein (GFP)-fused proteins, indicating that both proteins localized at the plasma membrane, vacuole membrane and perinulear membrane. These results suggested that TjZNT1 and TjZNT2 could function in selective-nutrient transport into cells or organelles under high Ni condition.

SESSION: *APPLIED ECOLOGY*
MODERATOR: DR. MARLA MCINTOSH

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ORAL PRESENTATIONS

076. IMPROVING THE AGRONOMY OF *ALYSSUM MURALE* FOR PHYTOMINING IN ALBANIA

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There are large areas of ultramafic soils in Albania with low productivity that are currently being used for agriculture. These areas could sometimes be suitable for phytomining provided that Ni

availability is high and soil deep enough. This is why we started investigating (field experiment) the performance of a low-cost phytoextraction with limited agronomic actions adapted to the Albanian context. We have been studying several soil management practices which may affect the efficiency of Ni phytoextraction in native covers of *A. murale* on 18 m^2 plots in natural conditions. In soil fertility management studies, we have used 120 kg ha^{-1} PK and 60 kg ha^{-1} N in the early vegetation period and 60 kg ha^{-1} N two weeks later. We found that NPK application significantly increased shoot biomass yield without reducing shoot Ni concentration. In weed control practices, we have used the anti-monocot herbicide (Focus^{TM} ultra) to allow for the full development of *A. murale*. We conducted a number of field and laboratory trials to define the optimal harvest time. In this three-year experiment, the biomass yields in fertilized and herbicide treated plots progressively improved (2.6-3.7-6.0 t ha^{-1}) and increased phytoextracted Ni (22.6-29.5-69 kg ha^{-1}). Such crop management practices improved phytoextraction efficiency, but when fertilization and harvest conditions were optimized, herbicide control did not improve efficiency. Extensive phytomining on such sites could be promising in the Albanian context by domesticating existing natural populations with fertilization and possibly no herbicide treatment.

077. ARBUSCULAR MYCORRHIZAL FUNGI FROM NEW CALEDONIAN ULTRAMAFIC SOILS IMPROVE THE TOLERANCE TO NICKEL OF ENDEMIC PLANT SPECIES

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The restoration of degraded serpentine areas after nickel exploitation needs ecological and microbiological knowledge. Our recent studies have highlighted the importance of arbuscular mycorrhizal fungi (AMF) in New Caledonian serpentine environments. Other studies have pointed out the ability of AMF to reduce the toxicity of Cd and Zn against plant species, in polluted soils. We aimed to investigate the influence of AMF isolates, from New Caledonian ultramafic soils on growth and tolerance to nickel of endemic plants. We initially tested this influence on sorghum as a model species and then used the same experimental procedures to assess *Alphitonia neocaledonica* (Rhamnaceae), an endemic plant species from serpentine maquis that is frequently used for ecological restoration. Two concentrations of Ni were tested with two AMF isolates in greenhouse conditions. Two other endemic plants, *Cloezia artensis* (Myrtaceae) *and Geissois pruinosa (*Cunoniaceae), were also assessed but with fewer treatments. The plant growth of these four species was clearly improved in presence of AMF. The inhibition of plant growth by Ni toxicity and the toxicity symptoms were significantly reduced in

mycorrhizal plants. More analyses were performed with sorghum and *A. neocaledonica*. The P absorption by these plants was enhanced, whereas Ni concentrations in roots and shoots were reduced by AMF. The mycorrhizal colonization of roots was moderately inhibited in the pots watered with 30 μg g^{-1} Ni solution and strongly inhibited in the pots watered with 60 μg g^{-1}. The sporulation of AMF isolates was also reduced by Ni. The most efficient isolate was more tolerant to Ni.

078. PLANT COLONIZATION LIMITS THE FIBRE DISPERSION IN AN ABANDONED ASBESTOS MINE

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Serpentinite exploitation for asbestos fibres has been widely banned since their inhalation can cause malignancies. Nevertheless, abandoned mines persist as sources of asbestos airborne dispersion. Vegetation cover has been intuitively invoked as remediation to limit substrate exposure and, consequently, asbestos dispersion. No studies, however, have evaluated if the poor vegetation which tolerates the serpentine factors and colonizes the abandoned mine spoils effectively reduces the airborne fibre quantity. We studied the largest asbestos mine in Europe (Balangero, Torino, Italy). Communities of *Thymus pulegioides* L. and *T. humifusus* Bernh. covered about 30% of spoil banks that have been abandoned since 1970. Metallophytic pioneer communities of *Minuartia laricifolia* (L.) covered 15% of the mining-terraces more recently abandoned since 1990. Uncolonized and plant-colonized plots (80 x 80 cm^2), subjected to mechanical ventilation and enclosed with a Plexiglas case (50 cm high), were sampled filtering 2.5 l min^{-1} of air for 30 min. The fibre dispersion was quantified by counting fibres observed on the filters at 500x magnification. Metallophytic and *Thymus* communities were analyzed at different stages of the vegetative season at least 10-days after rain. Plots colonized by *Minuartia* had a constant and significant 50% reduction of the fibre dispersion and fibre counts decreased from late spring to late summer. Plots colonized with *Thymus* communities also demonstrated significant reductions in fibre dispersion (40% to 65%) and showed strongly lower fibre counts than those of *Minuartia* areas. Early attempts to increase the *Thymus* cover in uncolonized areas through transplants gave positive results in terms of survival (95%) and dissemination.

079. SERPENTINE REVEGETATION CONCEPTS

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Serpentine landscapes are often disturbed by mining and road construction. Once barren, serpentine substrates are difficult to revegetate due to N, P and K deficiencies, low Ca:Mg molar ratios, potentially high levels of heavy metals including Ni, Cr and Co, low organic matter, low CEC and poor water-holding capacity. Drawing from research and providing examples of successful serpentine revegetation projects, this presentation will discuss important serpentine revegetation concepts including erosion control, soil amendment choice and method of application and revegetation plant species selection and planting.

080. RESTORATION OF INDIGENOUS VEGETATION AT SOLDIERS DELIGHT SERPENTINE "BARREN" IN THE MID-ATLANTIC PIEDMONT OF THE UNITED STATES

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Prior to English settlement (*ca*. 1750), an estimated 100,000 ha of serpentine vegetation was distributed in the piedmont of the State of Maryland and adjacent Pennsylvania on parallel bands of bedrock. Being bare of trees of timber size, settlers used the term "barrens" to categorize the landscape, and the serpentine outcrops became known collectively as the "Great Maryland Barrens." Vegetation was comprised mostly of grasslands and savannas maintained primarily by American Indian "fire-hunting" of white-tailed deer. Grassland dominants were little bluestem (*Schizachyrium scoparium*) and Indian grass (*Sorghastrum nutans*). Savanna tree species were predominately blackjack oak (*Quercus marilandica*), post oak (*Q. stellata*), and pitch pine (*Pinus rigida*) in varying combinations of relative abundance. Extirpation of American Indians by 1730 initiated ecosystem collapse though cattle grazing and logging of afforested areas helped maintain grassland "openings." By 1940, cattle grazing was no longer ecologically important and non-indigenous conifers, Virginia pine (*Pinus virginiana*) and red cedar (*Juniperus virginiana*), expanded across open areas. Soldiers Delight, the largest of the Great Maryland Barrens, supports about 400 ha of recoverable indigenous vegetation. Large-scale clearing of Virginia pine and prescribed burning began in the 1990s. Grassland and savanna communities have responded quickly to clearing and burning, but recent near-exponential growth of the white-tailed deer population and expansion of invasive plant species not native to the United States, especially Chinese sumac (*Ailanthus altissima*) and Mile-a-minute vine (*Persicaria perfoliata*), threaten past and future restoration efforts.

081. FIRE AND ULTRAMAFIC VEGETATION IN NORTHERN CALIFORNIA

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Ultramafic geologic substrates are well-known for their profound effects on vegetation structure. Ca:Mg imbalance, low macronutrients levels, and toxic metals lead to low primary productivity and low rates of biomass accumulation. Compared to more fertile substrates, the vegetation of ultramafic soils is often of lower stature, cover and density, soils are often rockier and frequently free of vegetation cover and there is relatively high light incidence at the ground surface. In Mediterranean-climate regions like California, fire plays an important role in structuring ecosystems, but ecosystems themselves also play a fundamental role in structuring fire. Here we report results of a comparative investigation into the contemporary fire regimes of ultramafic and "normal" vegetation across northern California. We used spatial data on bedrock lithology, fire history and severity, topography and vegetation to carry out analyses of fire occurrence and size, fire rotation and fire severity. We found differences in mean values across different geographic regions of northern California, but general patterns were congruent across the study area. Because of lower fuel loadings, ultramafic areas burn less often, at lower severity, and fires are smaller than in neighboring "normal" vegetation. Most fires occurring in ultramafic vegetation begin in surrounding non-ultramafic areas. When such fires encounter ultramafic vegetation, they often slow, become less severe, and sometimes stop. Through their ameliorating effects on the occurrence, spread and ecosystem impacts of wildfires, extensive areas of ultramafic forest in the Sierra Nevada and Klamath Mountains act as a system of natural fuel breaks. Conservation and restoration of natural fire processes in these places can provide both ecological and societal benefits.

082. GLOBAL CONSERVATION OF SERPENTINE ECOSYSTEMS: A CALL FOR ACTION

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The Millennium Ecosystem Assessment has effectively confirmed that biodiversity is essential for a sustainable planet. As a result, there has been a cascade of significant international activities addressing global conservation needs and priorities. A new paradigm has emerged for conservation planning and implementation that is based on ecosystems as the fundamental unit to conserve endangered species. Most conservation funds are used for local or national priorities, but flexible funding is available from multilateral agencies and foundations. Most international groups funding view “hotspots” that are “vulnerable” and “irreplaceable” as their highest

priority. By all measures, serpentine sites fit in these categories and occur as isolated fragments (of various scales) across the globe. The International Serpentine Ecology Conferences provide a forum for scientists involved in serpentine ecology to exchange and discuss new information and ideas. These conferences also have the potential to provide a framework to initiate an internationally organized effort to actively seek support for a coordinated effort to fund international efforts to conserve serpentine ecosystems. This presentation will propose ideas for developing a collaborative paper to make a strong case/statement for coordinated conservation of serpentine ecosystems. The goal would be to seek multinational funding for conservation of serpentine ecosystems as a global diversity priority. Suggested content for the paper includes (1) world-wide ecosystem assessment of serpentine regions, (2) identifying collaborative research needed to develop effective conservation strategies of serpentine ecosystems and (3) global climate change and using serpentine vegetation for scientific study and a genetic resource.

POSTER PRESENTATIONS

083. NICKEL HYPERACCUMULATION IN THE SERPENTINE FLORA OF ALBANIA AND GREECE

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Ultramafic soils are widespread over the Balkans. Albania and Greece are the richest in number of endemics growing on serpentine, including several hyperaccumulator plants; *Bornmuellera baldacii* (Degen) Heywood-GR, AL, *Alyssum markgrafii* O. E. Schulz ex Markgraf-AL, Leptoplax emarginata (Boiss.) O.E. Schulz – GR. The objectives of this study were to identify collection sites in which Ni-hyperaccumulator species occur and to understand the relationships between the Ni uptake by native species or population and corresponding Ni availability in soils across the two countries. Collection of both plant (analysis of element contents in aerial parts) and soil (analysis of total elements and DTPA-extractable Ni) samples allowed for the evaluation of the phenotypic and possibly genetic efficacy in hyperaccumulating Ni. The highest Ni content were found in *A. murale* in Pojska-AL (1.33 %), *A markgrafii* in Gjegjan-AL (1.23 %) (where DTPA extractable Ni was respectively 117 and 65.6 mg kg^{-1}), *B. baldacii* in Gramsh-AL (1.22 %) and *B. tymphaea* (1.17%), *L. emarginata* (0.95%) Monts–Pinde-Malakasi-GR and *Th. tymphaeum* (0.8%) Monts–Pinde-Katara-GR (where DTPA extractable Ni was respectively 126 and 65 mg kg^{-1}).We have identified new member of the Albanian Ni-hyperaccumulator flora: *Th ochroleucum* in Pojska-AL (0.13 % Ni) and in Pishkash (0.14 % Ni) for which DTPA extractable Ni was high 285-94.5 mg kg^{-1}.With regard to Ni availability in soils, *A. markgrafi*-AL is the

most efficient Ni-hyperaccumulator among the Albanian species. It is clear that the endemic *A. markgrafii* and also some efficient populations of *A. murale*, *L. emarginata* display the best Ni-efficiency for use in phytomining.

084. QUANTITATIVE MICRO-PIXE COMPARISON OF ELEMENTAL DISTRIBUTION IN MYCORRHIZAL AND NON-MYCORRHIZAL ROOTS OF NI-HYPERACCUMULATING PLANT

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Earlier reports on heavy metal distribution at the cellular/sub-cellular level of plants growing on metal-rich soil and being colonized by arbuscular mycorrhizal fungi have been restricted to non-accumulating plants. The present study is an assessment of the influence of arbuscular mycorrhiza on the concentration and distribution of elements in roots of the Ni-hyperaccumulating plant *Berkheya coddii*. The plants were inoculated with arbuscular mycorrhizal fungi or left uninoculated and cultivated under laboratory conditions on sterilized ultramafic soil. The elemental distribution in *B. coddii* roots and fungal hyphae was investigated with a nuclear microprobe, using micro-PIXE and micro-RBS. GeoPIXE II software package was used for quantitative elemental mapping complemented by data extracted from arbitrarily selected micro-areas. Analysis revealed significant influence of mycorrhiza on the concentration of elements in roots and shoots of *B. coddii*. Mycorrhizal colonization considerably increased P and K concentration in leaves and P, Ca, Zn and Cu in roots. The mycorrhizal fungi also affected the distribution of elements (P, K, Cl, Zn, Ni) within the roots. Strong visible accumulation of Zn within the cortex of mycorrhizal roots suggests that mycorrhizal fungus was involved in Zn sequestration. Significant increase of Ni concentration in vascular tissue of mycorrhizal plants in comparison to non-mycorrhizal ones suggests that mycorrhiza might affect Ni transfer from roots to shoots. The results obtained in this study indicate the necessity of including mycorrhizal research in phytoextraction projects and applications of mycorrhiza in phytoremediation.

085. SOIL AND PLANT COMMUNITIES OF A DUMP SITE IN THE LIBIOLA MINE (NW ITALY)

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The abandoned Libiola Copper and Iron Mine is situated in the Northern Apennines (Eastern Liguria, Italy) in an area mainly characterized by pillow basalts with minor serpentinites, gabbros and ophiolitic breccias. Several waste dumps, remnants of past mining activities, pose an environmental problem because of their dramatically high concentrations of several trace elements. The aim of this study was to compare the chemical and mineralogical characteristics of the dump sites and the corresponding floristic composition in order to elucidate ecological aspects of plants living in these extreme habitats. Three plots were selected and analyzed for trace element composition, main nutrient content and vascular flora. For each plot, biological and chorological spectra were calculated and the characterization of the floristic composition was defined based on the Grime's categories and the Landolt's ecological indexes. On the basis of these parameters, more representative ecological categories were characterized. Also, a preliminary screening for Ni content in plants was done in order to identify and evaluate the tolerance/accumulation behaviour of selected species growing on the study plots. This research is preparatory for the selection of plants useful for phytoremediation and habitat restoration in order to organize a management plan for the contaminated site. This plan should distinguish between areas of naturalistic relevancy, which need to be conserved, and areas which need to be reclaimed.

086. BIOGEOCHEMISTRY OF A FOREST WATERSHED UNDERLAIN BY SERPENTINE IN CENTRAL EUROPE

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The 22-ha Pluhuv Bor watershed is located in western Bohemia, Czech Republic, at an altitude of 690-804 m a.s.l. Precipitation, canopy throughfall, soil water and stream water were monitored from 1991 to 2008 at monthly or more frequent intervals. Bedrock, soil and tree tissue samples were analyzed, and development of soil and stream water chemistry in the period 1850-

2030 was simulated by the MAGIC model. The watershed is almost entirely forested by, on average, 100-year old Norway spruce (*Picea abies*) plantations. It is underlain mainly by serpentinite, but tremolitic and actinolitic shales and amphibolite outcrops are also present. Tremolitic shales and serpentinites are characterized by extremely high concentrations of Mg, Ni and Cr and by negligible concentrations of K, and therefore create an unusual environment for plants. Very slow spruce growth at Pluhuv Bor appears to be caused by K deficiency, Mg oversupply and Ni toxicity. Foliar Ca is in the upper part of the optimum range because shales and amphibolites in the watershed are important sources of Ca to the soil exchangeable pool and vegetation. The mineral soils exhibit high base saturation, reaching essentially 100% in the C horizon. Mineral weathering generates near neutral magnesium-bicarbonate-sulfate stream water with a high concentration of Ni. Stream water was partially acidified only during short-term hydrologic episodes when the runoff was dominated by flow through surface soil horizons. Bedrock geochemistry has a strong influence on element cycling and forest productivity at Pluhuv Bor.

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